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The Welsh Engineers' and Founders' Association
The Foundry Trades' Equipment and Supplies Association

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Ironfoundries and Substitution

The policy of the Ironfounders' National Committee is gradually bringing more and more work to the foundries, for it is taking advantage of every opportunity to drive home the directions in which cast iron can be used. There are four major fields, the most important of which is war and defence. The second, in view of the building programme, is the use of cast iron on, in and about buildings, of special interest to the light castings section of the industry. The third lies in the engineering industry, and the fourth in other producing industries requiring plant and equipment in which more cast iron can be used.

It is to assist the users and designers in these last three groups that the I.N.C. has addressed a letter to the technical Press, offering the assistance of the ironfounding industry in the present emergency and drawing attention to the progress the industry has made. As this question is mainly a technical one, and as recommendations must only be made when there is reasonable likelihood of the substitute giving satisfactory service, the I.N.C. is working closely with the British Cast Iron Research Association (the director of which is chairman of the I.N.C. Technical Committee). A panel of this Committee has already agreed on standard designs and has submitted them for official approval in connection with building plans and developments. Constant contact is being maintained wtih the great Departments of State to ensure that cast iron secures adequate consideration in all products where it is likely to be of service. In this work the existence of national specifications is of inestimable value, while the experience gained and work done during the past twenty years are equally so.

The I.N.C. has also invited the industry to express its views on suitable products which could, under present conditions, preferably be made in cast iron, and the excellent response is being examined. The whole question is naturally bound up with the work of the Control, with the supply of appropriate raw materials and with what might be described as the balance of national interest, and there is good reason for hope that before long the resources of the whole industry will be heavily engaged.

In the requirements of national defence and in the drive for export trade, much ordinary peace-time civil demand must go by the board, but the industry has the flexibility and the organisation to adapt itself to present necessities. Ironfounders may therefore with confidence support the activities mentioned, without, of course, relaxing for a moment their activities in endeavouring to fill their own shops.

The experience gained will be invaluable for the post-war period, and suppliers of plant and equipment will find plant demands in relation to new requirements tax their ingenuity. Altogether, regrettable as is the cause, the war is bound to result in a highly intensive development which should have a permanent value. The section having least ground for satisfaction is probably the highly-specialised vitreous enamelling section, which found its principal outlet in normal peace-time work.

Technical Literature

Added importance has to be attached to the various types of technical literature during times like the present, because so many people find that their normal activities are being extended to embrace new ventures. We are constantly being asked to recommend books dealing with this or that phase of foundry work or metallurgy, and quite often we are not satisfied as to the ultimate outcome. Starting with two premises only, it can be shown exactly where this difficulty arises. Because a paragraph is printed it is not necessarily true and authors of books are not masters of every phase with which they deal. A typical example can be given to exemplify this.

A foundry may be asked to make nickel cast iron and consult standard works on cast iron written twenty to twenty-five years ago. The information they would receive would be hopelessly misleading, as the authors of the books we have in mind would be the first to acknowledge. Yet, not knowing what phase of foundry practice the inquirer has in mind, it is easy to recommend the wrong type of book. It is now our practice to tell inquirers of the existence of the National Library, and to recommend its use through the local librarians. Further, we recommend that not one, but many, textbooks and articles should also be studied, and finally, where an appropriate bureau of information exists, its services should be utilised. Moreover, it is too little realised that the Proceedings of the Institute of British Foundrymen and the sixty-two volumes of THE FOUNDRY TRADE JOURNAL together constitute the finest works of reference of British origin. We acknowledge the great contributions made by other nations, especially the American and French, and fortunately their literature is readily available in this country.

The study of technical literature requires much discrimination, and it is only by consulting a number of authorities that a proper balance can be obtained. The date when the book or article

(*Continued on page* 250.)

Book Review

Quantitative Spectrographic Analysis with the Microphotometer. Part I, A Review of Published Work. By D. M. Smith, B.Sc., D.I.C., F.Inst.P., being Research Report R.R.A. 524 of the British Non-Ferrous Metals Research Association. Published by the Association, Euston Street, London, N.W.1. Price 2s., post free.

Rapid progress in quantitative spectrographic analysis during the past few years has been very largely due to the introduction of the microphotometer. This instrument provides a means of determining the relative blackenings of the lines used in the analysis with a precision far superior to that of visual observations by even a trained worker.

As a result of the much improved accuracy of measurement now available, the standardisation of electrical and optical conditions for routine analysis has been shown to require more rigid control than was formerly considered necessary. It is with the nature and control of the variables encountered in the standardisation of technique that this report is mainly concerned and, for convenience in reference, the various aspects of the subject are dealt with under the following headings:—Size and shape of the electrodes; The pre-sparking period; Illumination of the spectrograph; Blackening curves of the photographic plate; Interpretation of density measurements; Calibration of the photographic plate; Stepped-wedge and stepped-sector methods; Three-line method; Corrections for variable conditions; Choice of line pairs for measurement; Spectrum background; Effects due to alloying constituents; Effect of crystal structure and metallurgical condition; Industrial application of the method.

In the next section of the report, data for the analysis of alloys of aluminium, of copper, of lead, of magnesium, of nickel, of tin and of zinc (range of constituents studied, the line pairs measured, the source of the spectrum and the accuracy claimed) are summarised in tabular form, with reference to a bibliography of 54 publications.

This report forms the first of a series; succeeding ones will deal with experimental contributions to the subject from the Association's laboratories.

Technical Literature

(*Continued from page* 249.)

was published is of primary importance. The older textbooks are excellent for outlining the fundamental principles of foundry work and metallurgy, but for up-to-date specialised information they must be read with a good deal of reserve. It is desirable, if possible, to read literature germane to any particular phase in chronological order, for by so doing much time can be saved as each author, to expose his thesis, discusses the existing state of the art at the time of his writing—material which can be skipped over. Students will quickly realise that certain phases possess a plethora of excellent information, nickel cast iron being outstanding, whilst in other branches data are particularly meagre. In this case, a typical example is high-silicon acid-resisting cast iron. Again, there is a dearth of textbooks on steel castings, but happily this is made good by the large number of excellent articles written on this subject. The real object of this leader, however, is to assure our readers that, if they will consult us, indicating quite definitely which phase of foundry practice they wish to study, we will outline the necessary steps to take to acquire all the essential literature. Quite often, however, reference to published data can be usefully replaced by contact with an appropriate information bureau.

Notes from the Branches

LINCOLNSHIRE

At the meeting on March 16 of the Lincolnshire Section of the Institute of British Foundrymen, an address was given by Mr. F. Dunleavy on "The Foundry and the Metallurgist." Mr. Dunleavy in his characteristic style gave a brief history of the introduction of the metallurgist into the foundry, his early "martyrdom" and the general antagonism to the introduction of science, finishing with a picture of the metallurgist's position to-day. The discussion which followed had been skilfully provoked by the lecturer and was most valuable. Proof of the necessary co-operation was shown when a comprehensive question on one cupola being used to give irons of differing compositions was referred by Mr. Dunleavy to Mr. Harbach for corroboration.

WALES, MONMOUTH AND WEST OF ENGLAND

The annual meeting of the Wales, Monmouth and West of England Branch was held at University College, Cardiff, on March 16. The annual report presented by the hon. secretary showed that membership remained on the level of previous years, new members received into the Branch being offset by removals or withdrawals. The aim was to secure a membership of at least 100.

The following officers were then elected for the ensuing year:—*Branch-President*, Mr. S. Protheroe. *Senior Vice-President*, Mr. J. F. Gist. *Junior Vice-President*, Mr. H. J. V. Williams. *Hon. Secretary*, Mr. J. J. McClelland. *Branch Council*: Prof. W. R. D. Jones, Mr. D. Rogers, Mr. A. Dudley Haines, B.Sc., Mr. E. J. Kelly, Mr. M. Wayman, Mr. T. D. Richards, Mr. C. E. Williams, J.P., Mr. A. S. Wall and Mr. W. H. Thomas.

An interesting Paper was given by Mr. E. J. Kelly, who dealt with moulding problems, and the discussion of this Paper, owing to the limited time which was available, is to be continued at a later meeting to be held on April 13.

MR. T. MAKEMSON (General Secretary of the Institute), who was present at the meeting, referred to the wartime activities of the technical societies, and said that the Institute of British Foundrymen was carrying on more or less normally. It was now that the work of the Institute could be most valuable. The experience at the time of the last war was that, after a certain amount of hesitancy, the Institute increased its activities and membership, and Mr. Makemson saw no reason why the Institute should not now increase its present membership.

Mr. Makemson thanked the officers of the Branch for the effort they were making, and congratulated the Branch on its membership, pointing out that Mr. McClelland was still trying hard to make this 100. There were present a large number of young visitors, many of whom might find it helpful if they became members of the Institute.

(*Continued from third column.*)

Dr. Schofield, at the same dinner, also produced some witticisms of a different kind. Did he speak with fervour when he said that "an educationist is one who casts imitation pearls before real swine"? There are few who cannot appreciate the lawyer's grace as interpreted by Dr. Schofield, which goes, "To those we are about to deceive, make us truly plausible." Lastly, his plea that "a speech to be immortal need not be everlasting" is worth remembering by all whose lot it is to render "lip service" at dinners, especially if they come last on a long list of speakers.

"MARKSMAN."

Random Shots

It takes more than a war to break up the football coupon system in this country, and so ingrained has the idea become in the national character that even holidays have become tarred with the same brush. Easter this year has been a real "Coupon Holiday." Those who were lucky enough to take more than a few days from home began by handing in coupons to their landladies. Others, who merely went into the country for a couple-of-coupons drive on Easter Monday, on the other hand, could not miss the sight of fields full of young lambs, each representing at least a couple of coupons of a different sort in a severely practical world. But it is a shame to take so practical a view of those frolicsome woolly bundles, for they have been the chief source of delight so far in a Spring in which Easter has fallen so early as to find the countryside still devoid of green leaves and primroses.

* * *

Anyone who spent the Easter holiday in the country could not fail to notice the unsightly "dumps" of indestructible refuse which seem to infest the outskirts of many villages. "Marksman" found two such piles of rubbish in his week-end sojourn, and, sure enough, at one a group of enterprising young evacuees was scavenging for medicine bottles to be given to the doctor whom they knew was making his weekly visit that day. They must have rescued well over a hundred, if the weight of their basket was any guide! The other dump consisted mainly of old tin cans and presented a ticklish problem, for it would probably cost more in petrol to collect them than the scrap value warranted. The only way to overcome this difficulty would be to instal a hand press (if such a thing is made) on a lorry, and have it go round reducing bulk as it collects.

* * *

The utilisation of waste is not merely a wartime measure, however. An extract from "The Times" of a hundred years ago describes how a Frenchman converted dead horses, old leather and other odds and ends into gas for illuminating purposes. One dead horse was supposed to make well over a million cubic inches of gas. The idea, though at first well received, somehow did not "cotton on." Could it be that sausages were invented about the same time, thus robbing the other new industry of its source of supply?

* * *

Whilst talking of rural experiences, "Marksman" is reminded of the little boy who was spending Easter in the country with his family and who went running in to his mother, calling "Mother, I've just seen a man making horses. He's nearly finished one and is just nailing it's back foot on!"

* * *

A good story was told at the East Midlands Branch dinner by Mr. S. E. Dawson. A young moulder one day made three pipe moulds, all of which produced badly blown castings. The foreman grumbled about it and ordered more to be made. Unfortunately, the castings were again badly blown. Again the foreman reprimanded him, this time less politely, and with the threat of dismissal if better results were not produced. More moulds were made, and the foreman went over to watch the cast. He was delighted to find that each mould poured well and silently without ever a sign of blowing.

"Now why couldn't you do that at first?" he asked. "Well," replied the very young moulder, "I knew it was the cores that were blowing, so I've left the blank things out to-day."

(*Continued at foot of second column.*)

Large Electric Furnace Installation in South Africa

7½- TO 8-TON ELECTRIC ARC UNIT FOR CONTINUOUS OPERATION ON STEEL SCRAP

A large electric arc furnace has been installed in South Africa at the works of the Chamber of Mines Steel Products, Limited, Johannesburg. The furnace is for continuous operation on the melting of steel scrap of all types taken from various mines owned by the company. This includes shoes, dies, balls, wheels, worn-out rock drills, discarded steel cable and any other similar products, and the metal as poured has a carbon content of 0.7 to 1.0 per cent. The main production is billets used for making balls, shoes and dies. The furnace is a Birlec-Lectromelt unit by Birmingham Electric Furnaces, Limited. It is one of the standard range of sizes and is operated on a rating of 3,600 k.v.a. on 2,000 volts, 3 phase, 50 cycles, supply auxiliaries operating on 500 volts, 3 phase, 50 cycles. The capacity of 190 cub. ft. allows for a charge of 7½ to 8 tons and the time required to obtain a clear melted bath with a full cold charge, with the furnace already hot, is approximately 1½ hrs.

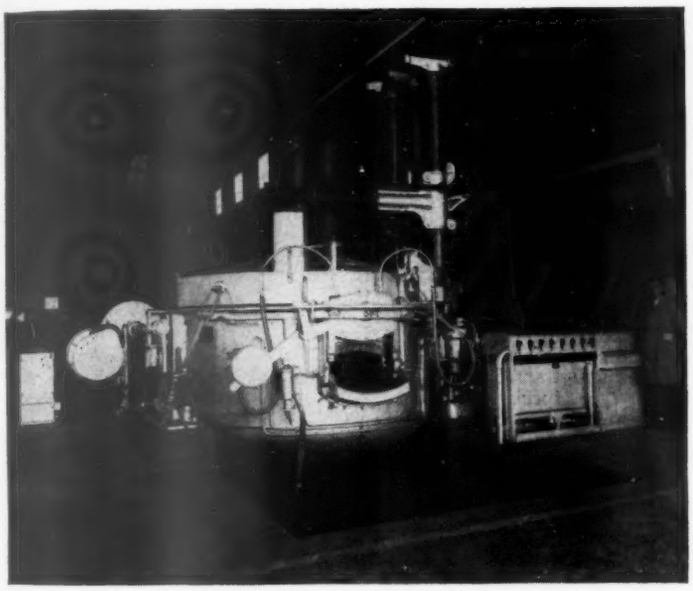


FIG. 1.—GENERAL VIEW OF INSTALLATION.

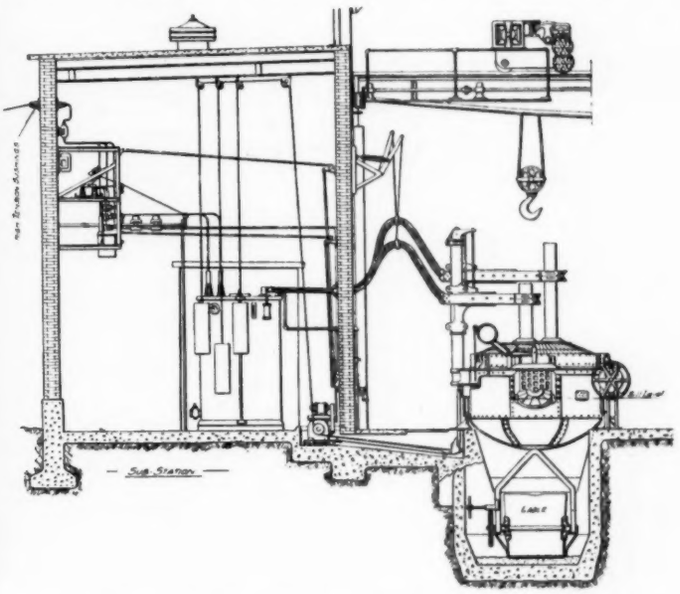


FIG. 2.—GENERAL ARRANGEMENT OF BIRLEC-LECTROMELT INSTALLATION.

Construction of Furnace Body

The furnace is cylindrical in form, with a dished bottom. It is constructed of heavy-gauge steel plates, welded and riveted, rivet heads being ground flat, giving an exceptionally clean external appearance. The casing is heavily reinforced with cast and structural steel members including a heavy, cast-steel top stiffening ring which is continuous across the door openings and entirely prevents distortion of the shell by heat. The furnace chamber is of approximately spheroidal shape, thus ensuring minimum heat absorption and minimum radiation losses.

The furnace roof is of arched construction, the refractories being seated in a heavy, channel-section steel roof ring, water-cooled on its outer circumference. The roof ring is designed for easy removal, enabling a new roof to be quickly installed while the original is being rebricked. The pouring spout is of heavy cast steel attached to the furnace casing by wedges which permit of its easy removal for lining. A large door is fitted diametrically opposite to the pouring spout for charging and slagging. This door has heavy, cast steel, water-cooled cheeks with machined water-cooled guides. The door is pneumatically-operated and is self-clamping in the closed position. This special design of door ensures that heat leakage is at a minimum and reduces electrode consumption.

Charging Arrangements

The furnace is arranged for top-charging by means of a drop-bottom bucket. The roof is lifted and swung aside by means of a hydraulic ram located immediately below the electrode masts and mounted in the furnace foundations (Figs. 5 and 6). The head of the ram is arranged to engage an eye-casting integral with the furnace roof and carrying the furnace masts. Separate pistons control the lateral movement of the roof.

When the roof is lowered to the working position, it is securely attached to the furnace casing by quick-acting adjustable clamps and the ram is disengaged, permitting the furnace to be tilted. The tilting and lifting mechanisms are interlocked to prevent the furnace from being tilted when the roof is raised.

Tilting Mechanism

The tilting gear fitted comprises a pair of heavy, cast-steel rocker trunnions mounted on either side of the furnace casing, having double-flanged treads running on track frames which incorporate teeth engaging with corresponding teeth on the rockers to prevent creeping. The rockers provide a wide angle of tilt—45 deg. forward for pouring and 35 deg. backward for fettling and slagging. They are designed to maintain the stream of molten metal from the pouring spout in approximately the same

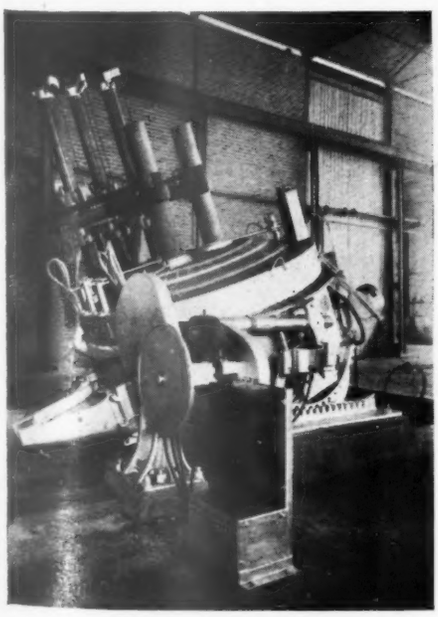


FIG. 3.—FURNACE TILTED.

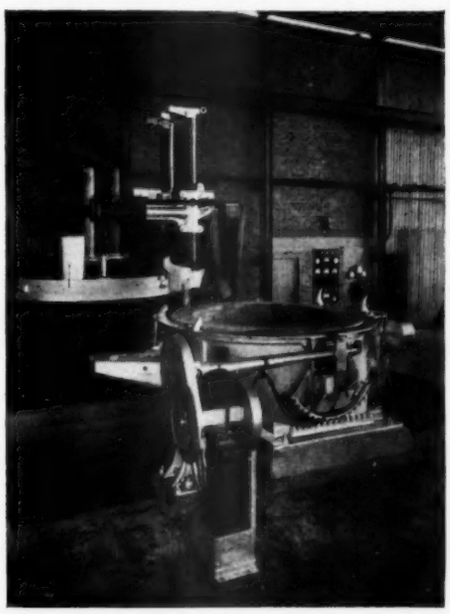


FIG. 4.—ROOF SWUNG CLEAR FOR CHARGING.

vertical line throughout the pouring, eliminating the need for moving the ladle.

The furnace is tilted by a steel screw engaging with a long nut attached to the furnace casing in swivelling trunnions. The screw thread is suitably lubricated and is encased in a telescopic dust guard. It is arranged for operation by electric motor or by hand-wheel. The whole of the tilting mechanism is above ground and is therefore immune from contamination by slag or dirt.

Electrode Gear

The three graphite electrodes, each 10 in. dia., project through the roof of the chamber

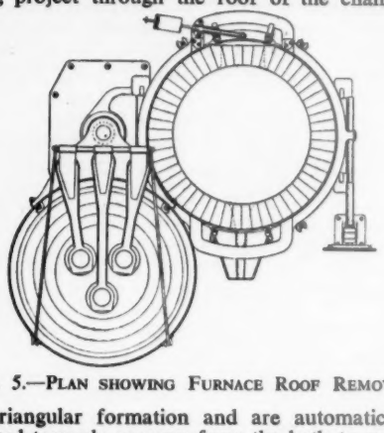


FIG. 5.—PLAN SHOWING FURNACE ROOF REMOVED.

in triangular formation and are automatically moved towards or away from the bath to maintain the required power. The electrode glands are of the water-cooled type, and are provided with expansion slots to prevent cracking in the event of failure of water supply. They are provided with luting rims to facilitate sealing of the furnace during shut downs. The electrode glands are supported by a special, insulated clamping device arranged to permit adjustment in three directions and mounted to compensate for expansion of roof refractories.

The electrode clamps are of cast, high conductivity copper, and are of the wedge type, designed to accommodate over-size or irregular electrodes. These clamps are mounted at the extremities of horizontal arms which, in addition to supporting the weight of the electrodes, are also the means of bringing the current to the electrode and of supplying the cooling water. The arms are of tubular construction and are constructed to give maximum rigidity and freedom from whip. They are of a design specially developed to minimise losses through eddy currents.

The electrode arms are attached to crossheads arranged to slide vertically on steel masts mounted at the rear of the furnace in a heavy steel casting integral with the furnace casing. The carriages are fitted with buffer springs and hardened steel rollers running in anti-friction bearings. The rollers engage with feather keys fitted in the masts, thus providing smooth vertical movement with minimum friction and absence of side-sway. The electrode carriages are suspended on flexible steel cables passing over ball-bearing sheaves, through the tubular masts and through ducts to the winches, the cables being carried beyond the winches to the counter-weights. The system incorporates compensating sheaves arranged to prevent movement of the electrodes when the furnace is tilted (Fig. 7).

The electrode cables are driven by motors and in order to avoid damage to the electrodes, the special friction-drive system permits the cables to slip on the drums if the electrodes are obstructed in their movement, either by coming into contact with the charge for instance or reaching the top of the mast. This arrangement obviates the use of limit switches.

A main high-tension truck type circuit breaker made by the English Electric Company, Limited, is provided in a cubicle in the substation, the switch being of 150,000 k.v.a. rupturing capacity, fully protected and provided with a no-volt release coil interlocked with the tap-changing switch on the furnace transformer.

Four single-phase, step-down transformers of the oil-immersed, indoor type, specially designed for furnace work, were supplied by the British Electric Transformer Company, Limited. These operate as a three-phase bank with one spare unit, for operation on the 2,000-volt, 3-phase supply. By means of tappings on the high-voltage winding a large range of voltages on the low-tension side can be obtained. Each transformer has a built-in variable reactor. The cooling equipment consists of a Serck cooler, with pumps and motor for circulating the oil.

The tilting motor is controlled by a tramway pattern, drum-type reversing manual controller, mounted in a convenient position. The main high-tension switch cubicle is fitted with voltmeter and ammeter, current and voltage transformers, and protective devices. In addition, a 3-phase, unbalanced load, integrating kilowatt-hour meter is provided. A separate instrument panel carries:—Voltmeter and six-way switch; indicating kilowatt meter; single-phase ammeters; synchronous electric clock; electrode regulator control; transformer tapping indicator lamps, and tapping-switch hand-wheel.

Electrode Regulator

Westinghouse automatic electrode control equipment is provided for controlling separately each of the electrodes by means of starting and reversing contactors, through which the winch motors are energised. By a special system, the

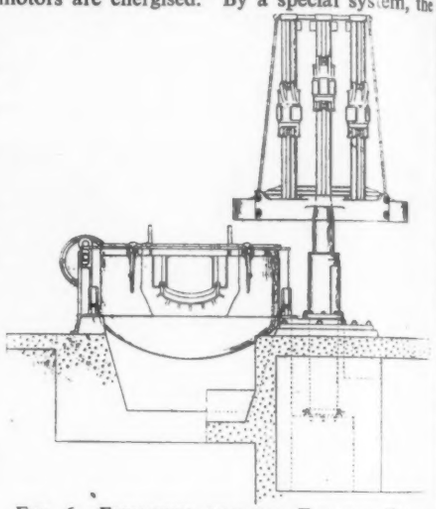


FIG. 6.—ELEVATION SHOWING FURNACE ROOF REMOVED.

effect of both current and voltage coils on the balanced armature is automatically reduced when the electrode has been brought by the winch motors close to the desired position. Final adjustment is obtained rapidly, but with great accuracy, by automatic inching of the winch motors provided under this system.

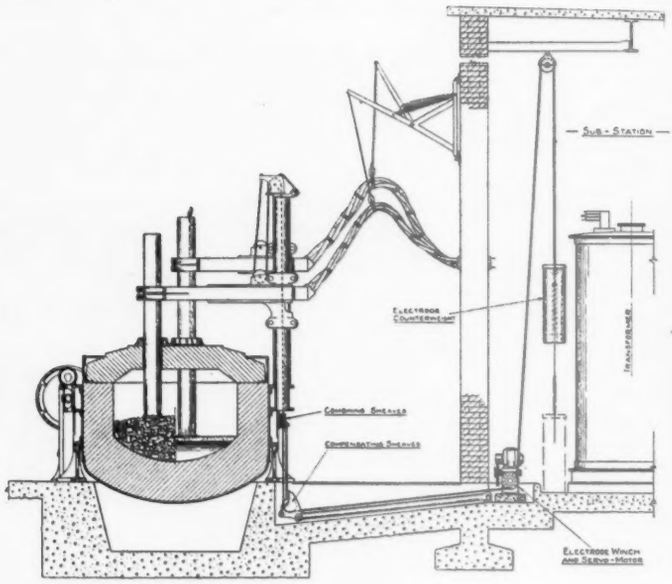


FIG. 7.—CROSS-SECTION SHOWING METHOD OF CONTROLLING ELECTRODES.

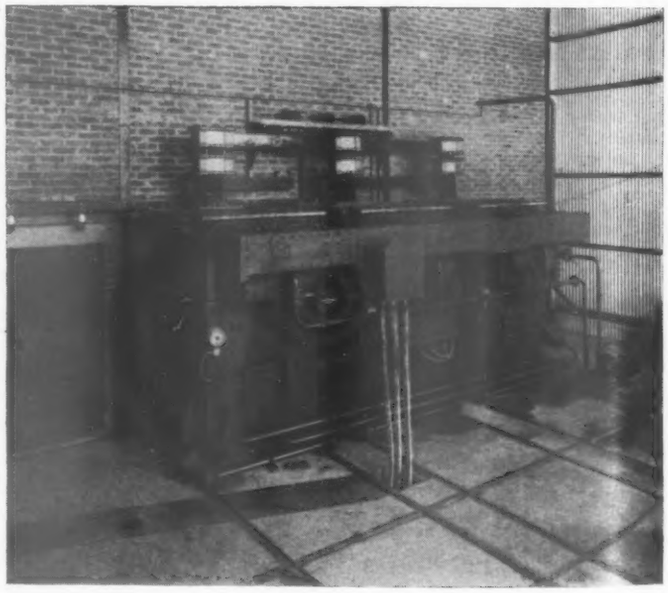


FIG. 8.—SOME OF THE ELECTRICAL EQUIPMENT.

The furnace can be charged in about five minutes, and the saving of time as compared with a fixed-roof furnace gives considerably improved production. The fact that a larger output is obtainable from a given size of furnace means that power, electrode and refractory costs per ton of steel poured are notably reduced. The furnace can be charged with scrap right up to roof level.

Gating and Feeding of Castings*

By ANTON JOHNSON

Gating and heading in a jobbing shop present many problems, due to the fact that changes in design to allow proper feeding are impossible, as the foundry is seldom consulted before the casting is designed and patterns are made. This makes it difficult to produce a sound casting without placing a considerable burden on the foundry, or even additional expense to the customer, in revamping the pattern before a satisfactory casting can be made.

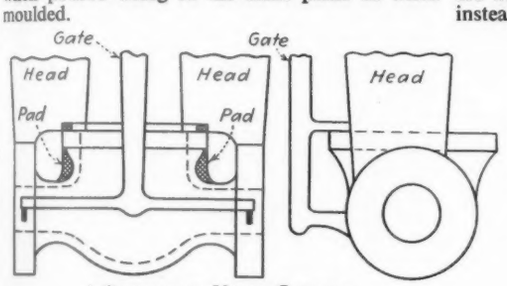
Factors Influencing Soundness

Fluidity of metal, the law of gravity and rate of solidification all enter into the making of a sound steel casting. Much can be said in favour of mould manipulation pouring and centrifugal pouring, but these methods can only be applied when design permits and they require extreme care and special rigging. Therefore, the following data will deal only with the orthodox manner of pouring, that is, the mould when poured being in the same plane as when moulded.

There are various kinds and ways of gating, and they all have their advantages—bottom or fountain, horn, bottom side in gate, gating on joint, step gates, top or pouring through head. These types are used single or multiple, according to size, shape and metal section of the castings involved. The aim in selecting a particular gate is to distribute metal uniformly to equalise shrinkage as much as possible and to avoid misruns.

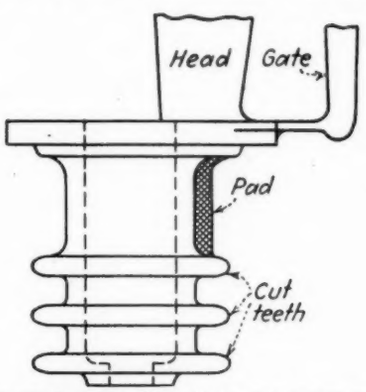
A very important part of gating is the proper making of gates, both down and ingates. The old, and still too often used, practice is for the moulder to use any stick or pipe that is close at hand, a practice inadvisable for several reasons. First, if too small, the casting may be badly misrun; if too large, metal is wasted, and a too large gate may even bleed the casting at the gate. Second, these sticks or pipes are very often rough or dented and may result in tearing apart the sand grains as these battered pieces are withdrawn from the mould, leaving a broken instead of a smooth sand surface. This makes it very easy for the rushing metal to cut into the disturbed sand grains, washing them into the mould and eventually trapping sand in the casting. Another cause of washed-in sand is improperly rammed and cut gates. A common sight is rough, knotty, irregular gates, due to soft ramming and careless cutting on the moulder's part. Carelessness or ignorance on the moulder's part in placing of gates is still another cause for cutting or washing of both mould and cores. Whenever possible, the gate should be placed so as not to let the metal strike hard against mould or core. This can be done by placing the gate parallel or at an angle to the mould or core surface.

(*Continued on page* 256.)

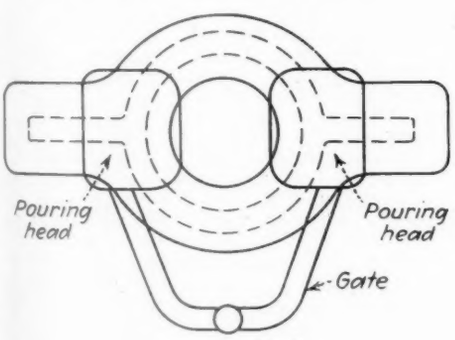


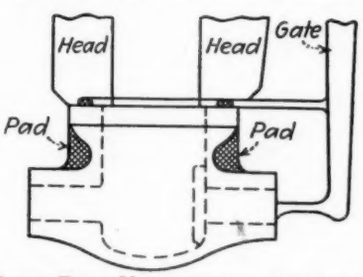
A Successful Valve Casting.

Bridge head feeding of both top and side flanges made it possible consistently to produce good castings. Note use of padding under the top flange to feed heavy body section.

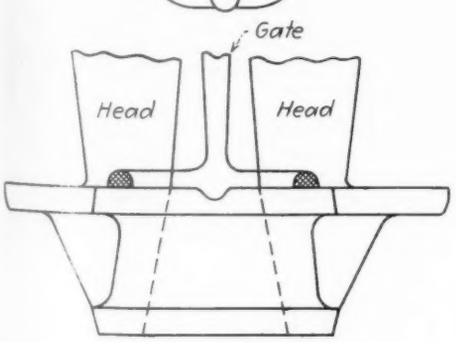


Blank Sprocket Cast Successfully with Top and Head Gating. Pads Allow Head to Feed Vital Tooth Sections.



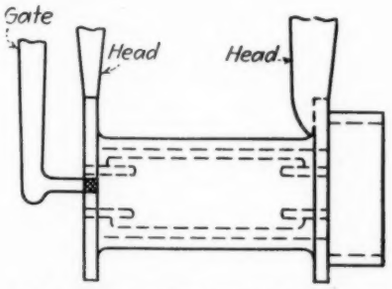


Screw-Type Valve which called for Joint and Head Gating. Pads under the Heads Help to Feed the Heavy Body Section.

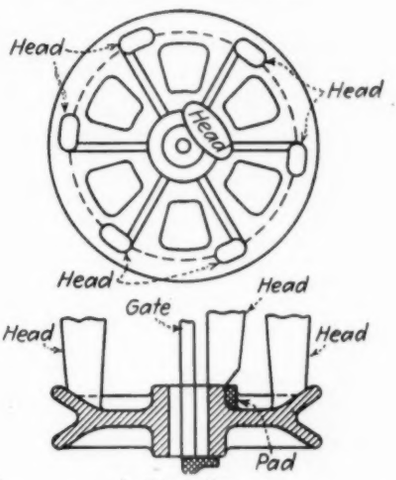


A Flanged Ring.

Gating this ring at the joints and into the heads proved to be an ideal arrangement, the result being cold metal at the bottom of the mould and hot metal in the heads where it was needed.

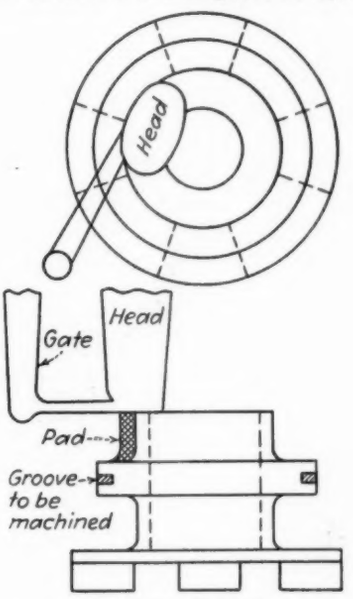


Cable Drum which was Gated into Light Flange and away from Machined Metal Inserts to Avoid Hot Spots and Simplify Heading.



A Cable Sheave.

Any blemish in the groove is detrimental to long cable life, and particular care in gating and feeding was necessary to eliminate the possibilities of defects at this point. A bottom gate into the hub, with heads at the intersections of groove and web, was used successfully in avoiding groove defects. Pad under the centre head serves to feed a dangerous hot spot.



A Clutch Casting.

It was imperative that the flange metal be solid to avoid losses in machining the groove. To ensure this soundness the casting was gated into the head with a pad leading from the head directly to the flange. The gate was cut at an angle to avoid cutting of cores. Gating from the bottom would have created numerous hot spots and shrinkage defects.

* Extracted from the "Iron Age." The author is works manager of the Oklahoma Steel Castings Company, Tulsa, Okla.

Electricity as Applied to Metallurgy

EXTRACTS FROM WILLIAM MENELAUS MEMORIAL LECTURE

At a meeting of the South Wales Institute of Engineers, held at Cardiff recently, MR. A. P. M. FLEMING, C.B.E., M.I.E.E., delivered the Thirteenth William Menelaus Memorial Lecture entitled "Electricity as Applied to Metallurgy."

The author pointed out that applications of electricity to industry and in fact to every phase of human existence increased year by year and the metallurgical industry was no exception; in fact, in certain phases of the metallurgical industry, electric power had a more than usual significant application. The author submitted Fig. 1 as giving a broad indication of the major applications to metallurgy classified under the headings, electrolytic, electro-thermal, electrostatic, metal working, and testing. The first two of these were perhaps the most direct applications.

Continuing, the speaker said electrolytic processes included such operations as the extraction of metals from ores, the refining of impure metals, electro-deposition of a given metal on the surface of another, with the object of providing a decorative finish or one which would be resistant to corrosion or abrasion, and anodic oxidation processes, the latter being so far confined mainly to the surface protection of aluminium and its alloys. Electro-thermal processes included numerous extraction and refining operations in the fields of ferrous and non-ferrous metallurgy, and also many different varieties of heat-treatment operation covering a wide range of metals and alloys. The various electric welding processes also came within this category. Some of the advantages of electric processing were increased flexibility, and greater purity of the final product. In furnace work higher temperatures could be attained and temperature control is more accurate, a large amount of energy could be liberated in a relatively confined space and could be applied just where required, whilst the inherent efficiency was frequently higher. Further, in some instances, *e.g.*, extraction of aluminium, electrical methods had proved far superior, both economically and from the metallurgical point of view.

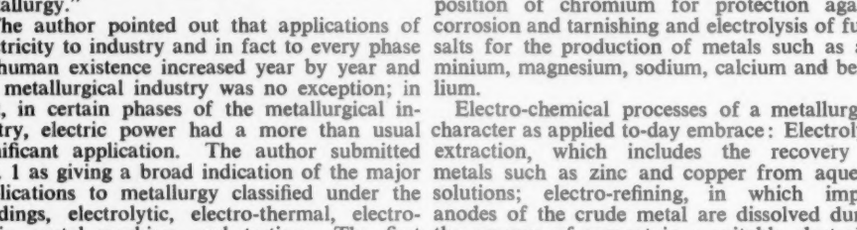


FIG. 1.—MAJOR APPLICATIONS OF ELECTRICITY APPLIED TO METALLURGY.

The historical development of electrolytic processes may conveniently be considered in three stages, the first dating from about 1800 to say 1836 covering the early experiments in decomposition of electrolytes and the discovery of the means of depositing certain metals. The second period from 1836-1870 was marked by considerable developments in primary batteries including the Daniell cell with its method of depolarisation, all of which provided stimulus for industrial development in the electro-deposition of metals. The third period from 1870 to the present time embraces the contemporary development of dynamo-electric machinery to provide electrical energy on an unlimited scale. Electro-deposition was applied extensively, and electro-refining of metals from their ores proceeded on an ever-expanding scale, notable examples being the deposition of chromium for protection against corrosion and tarnishing and electrolysis of fused salts for the production of metals such as aluminium, magnesium, sodium, calcium and beryllium.

Electro-chemical processes of a metallurgical character as applied to-day embrace: Electrolytic extraction, which includes the recovery of metals such as zinc and copper from aqueous solutions; electro-refining, in which impure anodes of the crude metal are dissolved during the passage of current in a suitable electrolyte and deposited in pure form on the cathode; almost the whole of the world's output of copper is refined in this way and the same general method applied to numerous other metals; electro-plating, which is perhaps best known as a means of producing special metallic finishes; electrolysis of fused electrolytes now widely applied for the extraction of certain metals of which aluminium is a typical example; and surface treatment, embracing all electrolytic cleaning and pickling processes.

Some indication of the electricity required and the cost of electricity in the production of certain metals is shown in Table I, which also gives an indication of the cost of electricity in relation to the selling price of the product. The yield of a product per unit of electrical energy varies enormously from one product to another, *e.g.*, the extraction of aluminium requires 9 kw.-hrs. per lb., whereas in copper-refining practice, the power consumption is approximately 0.08 kw.-hr. per lb. A noteworthy point regarding cost is that the majority of electrolytic extraction and refining processes work on a 24-hr. basis at steady load-factor and it has also been possible to do something towards adapting certain electro-thermal operations to make use of off-peak periods in the power supply. Consequently, it is usually possible to obtain electrical energy for these processes at reasonably attractive rates.

Electro-Thermal Processes

During the past decade or so, very great progress has been made in the science of metallurgy. In ferrous metallurgy great improvements have been made in the quality of steels, both carbon and alloyed, and the demands in such fields as turbine construction and aero-engine construction have put claims on the metallurgist for steels capable of withstanding increasingly arduous operating conditions. Such demands impose refinements in production, elimination of impurities, and scientific control of every process of melting and subsequent thermal treatment.

Applications of electricity in electro-thermal work may broadly be divided into those concerned with fusion and melting, and those concerned with heat-treatment processes. The three types of electric furnaces, namely, arc, induction and resistance furnaces, each has its own field of application. The total connected load of all types of electric furnaces in the United Kingdom at the commencement of 1937 was estimated to be not less than 150,000 kw. In 1935 alone, plant exceeding 30,000 kw. was ordered. The production of steel by the electric method in the United Kingdom has increased steadily in recent years, output having practically trebled between 1930 (76,000 tons) and 1937 (215,000 tons).

TABLE I.—*Electricity Required and Cost of Electricity in the Production of Certain Metals.*

	Electricity required per ton kw-hr.	Cost of electricity. £ per ton.	Approx. selling price. £ per ton.	Electricity cost as percentage of selling price.
Ferro-manganese (75 per cent.)	3,500	2·3	19	12·0
Ferro-silicon (45 per cent.)	4,500	3·0	11	27·0
Ferro-tungsten (80–85 per cent.)	8,600	5·75	524	1·1
Ferro-chromium (6–8 per cent. C)	7,000	4·7	23	20·0
Aluminium	18,000	12·0	94	13·0
Magnesium:				
Electrolytic	20,000	13·4	168	8·0
Electrothermal	24,000	16·0	168	9·5
Sodium	15,000	10·0	—	—
Calcium	45,000	30·0	—	—
Beryllium	65,000	43·4	—	—
Copper (extraction)	2,500	1·6	42	4·0
Copper (refining)	300	0·2	42	0·5

One of the earliest methods of electric welding was that suggested by the experiments of Joule, who in 1856 welded iron wires together by burying them in charcoal and heating with electric current. In 1877 Elihu Thomson, while experimenting with an induction coil, found that, on discharging a condenser through the fine wire secondary winding, a bright flash appeared at the ends of the heavy wire primary coil which were in contact. These ends were found to be firmly welded together. Based on this, Thomson built, in 1885, the first electric welding device, using a transformer to produce a relatively low secondary voltage which was applied to the pieces to be welded, the latter being held in contact by suitable clamps. This form of welding is known as resistance welding.

Arc Welding

Arc-welding processes followed the commercial introduction of the arc light in 1881. The heat of the carbon arc was blown by a jet of air on to the metal surfaces to be welded together, and later De Meritens substituted a single carbon as one electrode, the metal to be welded being the other. His process was further developed by Bernardos. The method has given way to the Slavianoff or metallic-electrode process of arc welding, in which the melt-bar or welding rod is used as one electrode, the other being the material to be welded. Development of this process was retarded until the introduction of suitable fluxes to improve the characteristics of the weld, after which the process found wide commercial application. Usually the flux is mixed with a refractory coating as initially devised by Kjellberg, the action of the refractory being two-fold, namely, it permits the electromagnetic effect of the welding current to act upon the molten metal so rendering overhead welding possible, and it applies flux at a rate that adjusts itself perfectly to the melting away of the welding electrode.

The author concludes with reference to resistance welding, to electrostatic precipitation and other miscellaneous applications.

Non-Ferrous Metal Melting Operations

PRACTICAL DISCUSSION IN MANCHESTER

Mr. Frank Hudson's Paper on "Melting Operations in the Non-Ferrous Foundry," which appeared in our issues of March 21 and 28, was presented at a joint meeting of the Lancashire Branch of the Institute of British Foundrymen and the Manchester Metallurgical Society, Mr. A. L. Key (President of the Lancashire Branch) occupying the chair.

Vote of Thanks

MR. NORMAN COOK, B.Sc., who proposed a vote of thanks to the author, said that he thought the Paper was the most interesting, from the practical point of view, that he had ever listened to at an Institute meeting.

MR. R. TURNER endorsed Mr. Cook's remarks, adding that he personally had learnt much from the Paper.

The vote of thanks was carried unanimously.

MR. HUDSON, responding, said there was much to learn about non-ferrous melting conditions, and he had described in the Paper one or two of his experiences which he could vouch for.

Segregation of Scrap

MR. A. SUTCLIFFE asked how the presence of manganese in gunmetal would affect colour and shrinkage, and what the effect of aluminium would be on the colour and skin of the castings. What had impressed him in brass foundries, where a number of heavy alloys were being handled, was the liability of the scrap runners to become mixed. An easy way of overcoming that difficulty was to mark the head or runner of each alloy used.

Many foremen did not like making alloys with a limited range of tin content, but preferred to have a free hand, asserting that better results could be obtained by using a small excess. Mr. Sutcliffe also asked for an opinion as to whether Mansfield red sand or yellow sand was to be preferred for brass moulding. He did not know whether the industry used the cheapest method of melting brass, but one at least was using the cupola with very good results

Influence of Mn and Al on Gunmetal

MR. HUDSON doubted whether small amounts of manganese had much effect on the colour, density or porosity of gunmetal, but aluminium had. Even a trace of aluminium (as low as 0.05 or 0.1 per cent.) would cause a white skin to form on the gunmetal castings, with appreciable porosity. So marked was this that if gunmetal containing aluminium were used for pressure work, leaky, unsound castings would be produced. Mr. Sutcliffe had remarked on segregation of scrap to the appropriate mixing. Such mixed scrap, however, could usefully be used for making the cheaper gunmetal, such as red brass (85:5:5:5). Every foundry should control tin within about ½ per cent. accuracy, although a variation of that magnitude would not seriously affect the properties.

Choice of Sands

The choice of Mansfield or yellow sand was quite open. Personally, he did not think there was one sand better than another, providing each possessed the suitable physical characteristics for producing good castings. In the production of special high-melting-point alloys in the brass foundry, such as Monel, etc., brass sands should never be employed. Ironfoundry sands carrying coal dust were called for. Brass foundries had received initial orders for these special alloys, and naturally had used Mansfield sand. The sand fused on to them, and created ugly castings. Brass foundries making such castings nowadays used ironfoundry sands, containing 5 per cent. or so of coal dust, and produced a beautiful blue skin like a grey-iron casting. For normal bronze work, a good Mansfield sand was in every way satisfactory. Many firms in the South used Erith sand, with equally good results.

Bronze Plate Castings

Dealing with some slides which were shown by Mr. Sutcliffe, Mr. Hudson said that for a bush which was depicted, his advice was to use no risers, but rather a good heavy ingate. A plate which was also shown reminded Mr. Hudson of a recent visit to a foundry specialising in the production of large bronze doors for buildings. Those doors were made up from a back and front plate, each only about ¼ in. thick, and the two were ultimately joined together to form the finished door, which would be about 10 ft. high and 6 ft. wide. It was no easy task to produce a bronze plate of those dimensions free from blemish. This particular foundry obtained very good results by pouring from about 10 ingates on each side, and using two big down-runners fed from two pouring ladles. To obtain the best results on plate castings, one should use dry-sand methods, and cast horizontally, with as many gates as one could get down one side or (if necessary) both sides. For bronze castings, risers should be avoided if at all possible.

Melting Losses

MR. A. PHILLIPS remarked that in the table showing the melting losses under oxygen, nitrogen and hydrogen, no test had been taken on the phosphorus alloy melted under nitrogen. As to sodium-zinc additions for releasing gases, he would like to know how to add the sodium-zinc under foundry conditions. The same remark applied to the copper oxide. It had been stressed that alloys containing aluminium could have the oxides reduced by phosphorus additions except the actual aluminium oxides. What could be suggested for the reduction of the alumina in such cases?

MR. HUDSON, referring to the table showing the effect of phosphorus on brass and the zinc losses under reducing and oxidising conditions, suggested that the only reason that the nitrogen test was omitted was because there was no difference between oxidising and reducing conditions. It was not worth while doing a test on the phosphorus brass with the neutral atmosphere, because quite obviously the result would be the same.

The sodium-zinc development had not made (so far as he knew) any progress in this country, but it had been employed in America. Apparently this deoxidiser was an alloy containing 2 per cent. sodium and 98 per cent. zinc in metallic form suitable for adding to the metal by plunging. Copper oxide could be added in two ways. Cupric oxide was usually added in the crucible with the initial charge, while cuprous oxide was usually made up into a packet using copper foil as an envelope, or packed inside copper tubing, and was then plunged below the metal surface.

He did not know of the existence as yet of any positive method of reducing aluminium oxide. He believed that one or two people specialising in the production of aluminium bronze used a certain flux, which effectively reduced aluminium oxide. This probably contained a cryolite base. In the refining of aluminium, bauxite containing aluminium was dissolved in cryolite. He thought a flux containing cryolite might be effective, but he could not put it forward with any degree of confidence.

MR. N. COOK said a proprietary flux was being sold to remove small amounts of aluminium from gunmetal and bronzes.

MR. HUDSON, although aware of such a flux, said that he had had no experience of its use in practical conditions.

MR. COOK added that he was informed that excessive additions would make it ineffective.

MR. PHILLIPS said that for some time the firm with which he was associated had observed the practice stressed in the Paper of having oxidising conditions in melting. He was fully in agreement with the author; oxidising atmospheres were quite satisfactory for the brasses and the bronzes, but with aluminium alloys such atmospheres during melting were the reverse and must be avoided at all costs because they were unable to free the liquid metal from the oxide.

MR. HUDSON agreed, and said he had purposely confined his remarks to the copper-base alloys, because he did not want to give an impression that his remarks referred to the aluminium alloys or to alloys containing aluminium.

Use of Sodium-Zinc

MR. D. FLEMING said his firm had tried using 2 per cent. sodium-zinc alloy made by adding sodium to zinc in the molten condition. This might sound a highly dangerous procedure, but was quite easy. He used the sodium-zinc in place of the normal zinc. Tensile tests of over 20 tons for gunmetal had been claimed, but he had not found it to be as beneficial as it promised to be initially, and its use had been suspended for further investigation.

MR. PHILLIPS thought sodium-zinc was beneficial in certain directions. He had tried some experiments, but was not yet fully convinced, or he would have given the results. He did think that sodium-zinc would help to remove aluminium oxide. He had no definite data as yet, but work had been done in that direction which revealed very favourable aspects.

MR. HUDSON pointed out that both sodium and potassium were much more powerful reducing agents than phosphorus, and there were very few metals which sodium and potassium would not reduce from the oxide to the metallic state. There was every reason to think that tests with either of those two metals would be very satisfactory.

MR. FLEMING said he was not referring to sodium-zinc as a remover of aluminium oxide, but as a deoxidiser.

MR. VICKERS asked whether the remarks on aluminium oxide were in reference to aluminium bronze, aluminium itself, or aluminium alloys.

MR. PHILLIPS said he was referring to aluminium oxide in any of the aluminium alloys containing it, such as aluminium bronzes, or any other bronzes containing aluminium. That was his initial inquiry.

Zinc Chloride Championed

MR. VICKERS then observed that in those circumstances with the three alloys mentioned, zinc chloride would remove aluminium oxide. That fact he had actually proved. He had seen material containing so much oxide that one could melt and obtain only a spoonful of metal, and one would get back 98 per cent. of the material as metal when using zinc chloride.

MR. TURNER said that for gunmetal his firm was using 0.2 per cent. zinc as deoxidiser and the best results were obtained. He believed that Mr. Hudson had recommended phosphorus. Did any of the phosphorus remain in the metal, and did it improve the strength or otherwise?

MR. HUDSON replied that the amount which remained was practically undetectable by normal routine analysis.

MR. TURNER inquired whether phosphorus gave better results than zinc as a deoxidiser.

MR. HUDSON replied that phosphorus, in conjunction with zinc, would give better results, as there was 2 per cent. zinc present initially.

MR. TURNER said his firm always added a further 0.2 per cent. as a deoxidiser.

MR. HUDSON thought that, in the circumstances, the addition of 0.05 per cent. phos-

phorus would give even better results than increasing zinc solely, or using zinc as deoxidiser. The most important factor was to obtain oxidising melting conditions in the first place. Phosphorus additions did not degasify and their full benefit was not developed if the metal was improperly melted in the first place.

Cupola Melting

MR. SUTCLIFFE asked what Mr. Hudson thought of the practice of melting gunmetal in the cupola.

MR. HUDSON thought that under certain conditions this could readily be done. He knew of at least one foundry which made large quantities of gunmetal in the cupola, but it was not employed for direct casting operations. Non-ferrous foundries producing large outputs of gunmetal and bronze castings could put all the more contaminated products from the reclamation plant through the cupola, at the end of the day, and cast the metal into ingots for remelting purposes. A good yield of ingots was thereby obtained. That was one way of utilising the cupola, but they still remelted in crucibles afterwards. Cupola melting was an uneconomical way of melting gunmetal, unless one had large quantities of low-value material which had to be cheaply reverted to a more marketable or usable form.

MR. J. MASTERS recalled that, some 30 years ago, his then employers rigged up a cupola purposely for melting copper, with a view to adding the alloys after the copper was melted, but it proved a total failure. There was not a sound casting in a batch consisting of about 15 tons, mainly of brass axle boxes.

MR. A. E. MCRAE SMITH said that on one occasion his firm was compelled to use the cupola for a huge supply of high-pressure copper tubing. Melting was accomplished by using a very low blast pressure.

MR. W. HOLLAND said that up to 12 months ago, a firm in Gloucestershire was actually melting bronzes in a cupola. They maintained a cupola specially for that purpose.

MR. HUDSON said it had frequently been done in America.

MR. HOLLAND added that the castings were not for pressure-resistance, but were statues and art castings. The metallic losses were high.

The CHAIRMAN (Mr. A. L. Key) recalled that at the time he served his apprenticeship, all his firm's heavy non-ferrous castings were cupola-melted, and they passed Admiralty tests quite successfully. One could imagine the care necessary with a condenser taking 4 tons of metal which were melted in the cupola. The zinc and tin had to be alloyed in the ladle. There was no other means then of doing the job. Now an air furnace was invariably employed. Mr. Key added that he knew of one firm which had recently erected a cupola for the purpose of making antimonial lead, which had always been melted in pots previously. The firm was employing this cupola quite successfully, and as economically as the crucible process.

Flame-Hardening Process

A higher degree of hardness in steel and alloy iron rolls and the like is being obtained by a new flame-hardening process developed by Linde Air Products Company, and in operation at the plant of Farrel-Birmingham Company Inc., Ansonia, Conn., according to a note in "Metals and Alloys." By the use of this process, which is known as the "vertical combination method," the Farrel-Birmingham concern is able to raise the hardness of a 0.65 to 0.75 per cent. carbon-steel cylindrical object to approximately 90 or better on the Type C Scleroscope. The company has also tested the process in hardening a special dry-sand alloy cast iron known as "Farrelflame," and has obtained an average hardness of 80 on the Type C Scleroscope. An advantage claimed for this flame-hardening process is that in all the rolls hardened by its use no measurable distortion has been detected.

Expanding Capacity at Tata Works

To enable India to add further to its economic self-sufficiency, particularly with regard to army and railway supplies, an elaborate programme of extensions during 1940 has been planned for the Tata Iron and Steel Works, Jamshedpur.

A new "A" blast furnace with a daily productive capacity of 1,000 tons has already started operation and within a week reached capacity, the exact output being 1,019 tons. This furnace, which makes a total of five furnaces at Jamshedpur, will raise Tata's productive capacity of pig-iron to 1¼ million tons per year. The company has undertaken the installation of the plant for the manufacture of wheels, axles and tyres, required under the recently approved scheme of the Railway Board, for the large-scale manufacture of locomotives in India and to the self-dependence of India in the supply of all forms of rolling-stock. The plant has been ordered from abroad and will come into operation within the next 18 months.

Indian rights have already been acquired for a new process of manufacturing acid steel entirely from Indian materials. An additional steelmaking plant and a 50-ton acid open-hearth furnace are being installed which will increase the company's steel-producing capacity by about 200,000 tons a year, of which 50,000 tons would be acid steel. Plans are already in hand for the installation of a billet mill to roll billets suitable for several types of small and medium forgings, an ingot mould foundry to increase the output of castings, and a plant for the extraction from coke-oven gases of benzol and toluol.

During 1939-40 it is estimated that the production of steel ingots will be in the region of 1,000,000 tons and that of finished steel 750,000 tons, which will rise further to 800,000 tons in 1940-41. When the programme of extensions now in hand has reached completion, the company's production will have touched a new record figure of nearly 1¼ million tons of steel ingots and about 900,000 tons of finished steel.

Gating and Feeding of Castings

(*Continued from page* 253.)

Tile or Core Gates Recommended

To avoid some of these bad practices, the writer recommends the use of tile or core gates. For light- and medium-sized work a core gate is very satisfactory. The well-known saying that "A chain is no stronger than its weakest link" can be adapted to "A casting is no cleaner than its gate."

The improper placing of the gate often causes hot spots in casting that cannot be fed, resulting in shrinkage cavities to be found by the customer, sometimes only after considerable expense.

Heading has a direct relation to gating. The gate permits the metal to enter the mould, and the function of the head is to pack the metal in, or to feed the casting.

Feed Heads Important

The part of the casting at which the metal enters will stay the hottest, provided the metal sections are uniform. If they are not uniform, shrinkage and cavity problems are increased. It is, therefore, important to determine which part or parts will be affected by the temperature of metal at the gate as well as at the heavy sections and intersections, where hot spots are likely to occur. These are the places where feed heads should be placed and the gate should be kept as close to one of these as possible in order that the head can so feed as to minimise hot spots. By a natural hot spot is meant one caused by heavy sections or intersections. The artificial hot spot is the one caused by the gate. It is necessary, therefore, to have in some instances as many heads as there are hot spots, regardless of whether naturally or artificially created.

The most common position to place heads is on the uppermost part of the casting, but it is often necessary to place them on sides or even at the bottom, especially in cases of heavy metal sections that cannot be fed due to the lighter metal sections above, or due to having the gate into the bottom, thus causing a hot spot. In order to feed some non-uniform metal sections, it is often necessary to resort to padding.

The class of work made by Oklahoma Steel Castings Company consists largely of oil-country castings of various shapes and weights and must meet the most exacting requirements. Each casting presents a different gating and heading problem. A few of these jobs are illustrated herewith. Excellent results were obtained by using the gating and heading methods shown.

The author wishes to express his appreciation to Mr. William Kunz and Mr. Hugh Coshow for their assistance in preparing this report.

Workmen's Compensation Commission

SILICOSIS AND ASBESTOSIS

Some very specific recommendations concerning the treatment of silicosis and asbestosis under workmen's compensation were made when the National Conference of Friendly Societies, representing some 4,400,000 adult members, gave evidence before the Royal Commission on Workmen's Compensation, sitting at Thames House, Millbank, London, S.W., his Honour Judge Stewart presiding.

Experience since the inception of the Schemes under Section 47 of the Act of 1925, observed the Conference, had shown how extraordinarily difficult it was for a workman to establish title to the protection of the Act, as there was substantial difficulty in diagnosis, even by experts. A workman suffering from these diseases was at a great disadvantage compared with a workman who sought to recover compensation in respect of one of the diseases mentioned in the Third Schedule of the Act, or in respect of personal injury arising out of and in the course of the employment.

Recommendations

The Conference therefore recommended:—

(*a*) That every workman, no matter in what processes, or group of industries, he be employed, who contracts silicosis or asbestosis, be entitled to compensation in respect of loss of earning power resulting therefrom whenever such occurs, and that the limitation of three years imposed by Article 4(3) Proviso B of Part I of S.R. & O. No. 342 be abolished; (*b*) that employment in a specific industry, and not a particular process in the industry, should be the basis of such claim; (*c*) that employment in the industry, however short, shall be sufficient to substantiate a claim in respect of silicosis or asbestosis; (*d*) that periodical medical examinations be required of workmen employed in all industries where the possibility of silica or asbestos dust arises; (*e*) that when, on examination, a workman is found to be not totally disabled, but suffering from silicosis or asbestosis to such a degree as to make it dangerous for him to continue in the industry, he shall be suspended from employment, but shall be entitled to compensation and medical treatment during such period of suspension until such time as suitable employment can be obtained; (*f*) that the high fees for medical board certificates authorised in the Silicosis and Asbestosis Medical Fee Regulations be greatly modified.

The suggestion that the Schedule of Industrial Diseases and all the Silicosis Schemes under the Workmen's Compensation Acts should be abolished, was made by the Parliamentary Committee of the Co-operative Congress when it presented evidence before the Commission. In the place of the Schedule and the Silicosis Schemes the Parliamentary Committee proposed that there should be the general qualification that "a workman should be entitled to compensation whenever he contracts a disease attributable to his employment."

A Laboratory Gas Furnace for Very High Temperatures*

By VAUGHAN H. STOTT, D.Sc.

The furnace to be described was developed in the course of work on the sintering of alumina. For this purpose a temperature of 1,750 deg. C. suffices, but the time of firing may be considerably reduced if 1,800 deg. C. is attainable. Since the chief purpose of the furnace was the firing of alumina, it was natural to use pure alumina bricks for the hottest parts. The chemical activity of alumina limits the useful temperature when other materials are to be fired, and for this reason temperatures above 1,800 deg. C., although attainable, are rarely required. It is sometimes possible to avoid chemical difficulties by arranging for the contact of dissimilar materials to occur in a cold part of the furnace, but in the case of gas furnaces intended for miscellaneous work this arrangement leads to difficulties in design and upkeep. On the assumption that the objects to be fired rest on supports which are wholly subjected to the highest temperatures of the furnace, alumina is probably the best refractory for work of a varied character involving temperatures not greatly exceeding 1,800 deg. C.

In addition to the difficulties arising from the deterioration at high temperatures of a refractory material in the neighbourhood of its contact with a second material, trouble may be caused by the tendency towards crystal growth which is characteristic of pure substances at elevated temperatures. Crystal growth not only results in shrinkage of the overall dimensions of porous pure refractories, but may also be the main cause of the slow yield of pure refractories, whether porous or not, under stress at high temperatures, the movements of the crystal boundaries tending to relieve the strains in the material. Yielding of materials in this way can be minimised by arranging for the stresses to be as small as possible in the hottest parts. The cracking and spalling of refractory materials under the influence of stresses set up by thermal, mechanical or chemical agencies are sources of trouble in most furnaces, but their effects are aggravated at very high temperatures.

To overcome the various difficulties outlined, simplicity in design may be necessary even when achieved at the expense of the initial efficiency of the furnace. Provision must always be made to retard as far as possible the deterioration of the furnace which results from use. For example, the lining of the furnace used in the National Physical Laboratory to test Seger cones† was formed as a single block of alumina, the plan of the exterior being a square with 9-in. sides. After the first heat such a block contains cracks; but, the block being small, the cracks are narrow, and the heat flowing through them is insufficient to damage the surrounding material, which is, of course, less refractory than the inner block. For a somewhat larger furnace, such a design leads to cracks through which the flow of heat causes failure of the outer refractory materials. This difficulty is surmounted by building the lining of separate small bricks, so that the cracks will occur between the bricks. With a sufficient number of joints, the width of each crack becomes too small to permit the passage of enough heat to cause damage.

The ease with which high temperatures are attained in the furnace to be described is due primarily to the use of a burner‡ in which the gas and air are so intimately mixed that combustion is very rapid, resulting in a high optimum gas consumption. This feature is combined with very efficient heat insulation. In connection with the latter, it is important to prevent serious loss of heat by radiation. At a temperature of 1,800 deg. C., a direct radiation loss from a surface of 1 sq. in. may not be negligible in comparison with the heat lost through the brickwork of a furnace of about the size of that in question. Precise knowledge of the latter loss is not available, but the lowering of the maximum temperature attainable resulting from a direct radiation loss may easily be observed. It should be noted, however, that heat lost by radiation to the burner is largely retained by the gases passing through it, and does not appreciably impair the efficiency of the furnace.

Construction of Refractory Lining

The main features of the furnace are illustrated in the sectional plan of the brickwork at a height 1 in. above the hearth (Fig. 1); that is, the section passes through the centre line of the burner hole. The tapered bricks, which form a lining approximately 1½ in. thick, consist of 80 per cent. fused alumina of 220 grit bound with 20 per cent. of calcined alumina ground wet for five hours in an aluminium mortar, and fired to at least 1,800 deg. C., the shrinkage for this temperature being about 3½ per cent. (Alumina which has been ground wet in an aluminium mill contains a little colloidal aluminium hydroxide derived from the action of water on the abraded particles of aluminium. The hydroxide has valuable binding properties.) The bricks are fired in a temporary furnace of which the lining is less shrunk than is desirable in a more lasting furnace. Even after firing to 1,800 deg., the alumina bricks are very porous and can be cut with a hacksaw. The burner block is made of the same material, but is fired to cone 20. The burner block and the tapered blocks are all 3 in. high.

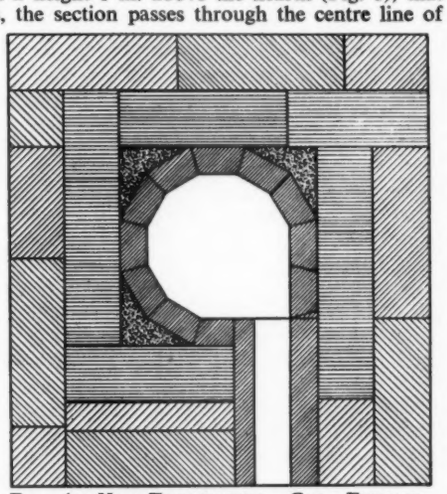


Fig. 1.—High-Temperature Gas Furnace. Section Plan 1 in. above Hearth. Scale ½.

The complete furnace contains three more courses of tapered lining bricks, making its internal height 12 in. The bricks in the second course form a regular dodecagon. Except for a bridge near the burner brick, each tapered brick in the second course is vertically above the corresponding brick in the bottom course, and the third and fourth courses are similar. There seems to be no disadvantage in the straight vertical joints thus formed, and it is easier to build the furnace in this way than to break the joints. (The latter arrangement has, however, been used.) The top course of the hearth, on which the inner lining of the furnace rests, is composed of the standard tapered bricks laid with the parallel sides horizontal, the longer side of one brick being adjacent to the shorter side of the next. Pointing is done with a brush, using a very fluid slip containing the same mixture as is used in making the bricks. The bricks shown in the diagram with horizontal shading contain equal parts of "Triangle patching material with grog" obtained from The Morgan Crucible Company and the calcined pure alumina which is a standard product of the British Aluminium Company. Firing these bricks to cone 20 produces a negligible shrinkage, and the fired bricks contain a large number of fine pores, so that the material is a good heat insulator.

Thermal Properties

The thermal conductivity of similar bricks containing rather less alumina (40 per cent. instead of 50 per cent.) has been determined by Dr. Ezer Griffiths, F.R.S., of the Physics Department, who obtained the following results. The value in gramme-calories per square centimetre per second for 1 cm. thickness and 1 deg. C. difference in temperature for a mean temperature of 772 deg. C. (hot face 1,064 deg. and cold face 480 deg.) was 0.0011. For a mean temperature of 1,080 deg. C. (hot face 1,516 deg. and cold face 644 deg.) a value of 0.0016 was found.

Into the corner spaces between the tapered fused alumina bricks and the clay-alumina bricks are wedged pieces of well-shrunk fused alumina bricks, the crevices being filled with a very fluid clay-alumina (equal parts by weight) slip made up with water.

The outer parts of the furnace consist of high-quality insulating bricks capable of withstanding 1,500 deg. C. on one face without serious deterioration. Beneath the refractory hearth is a course of clay-alumina bricks, the bottom course consisting of insulating bricks. Except for the fused alumina bricks and the corner fillings, the bricks are standard squares 9 in. by 4½ in. by 3 in., a few being cut where necessary. It may be noted that the height of three 3-in. courses of tapered lining bricks, together with the hearth lining of 1½ in., is 13½ in., which is equal to the height of three courses of the surrounding bricks which are set on their narrower faces. The fused alumina burner brick is 9 in. by 4½ in. by 4½ in., the bottom of the circular hole of 2 in. diameter being at the level of the hearth. The whole of the inside of the furnace is treated with fused alumina slip applied with a brush, and this treatment is used as a substitute for pointing throughout the life of the furnace. The hotter parts of the top of the furnace are levelled by means of the same mixture, a mixture of clay and alumina being used for the cooler parts. Tie-bars clamp each course fore and aft and from side to side. They are not adjusted during heating or cooling.

Furnace Roof

Since the roof of the furnace is removed for each charge, it is laid without jointing material. The furnace opening is almost completely covered by means of two 9-in. by 4½-in. by 3-in. fused alumina bricks laid as stretchers of 3 in. height so as to leave a small opening at the front. Cut fused alumina bricks are then arranged so as to leave a triangular aperture of from ¼ to ¾ sq. in. above the burner. This aperture serves as an exit for the flame gases, which issue almost vertically, and as a sighting-hole for the optical pyrometer, which is inclined at an angle of about 45 deg. to the vertical.

The alumina bricks are surrounded (except in the line of sight of the pyrometer) by bricks consisting of alumina and grogged clay. The latter bricks are also used for a second 3-in. course

* Reprinted from the Transactions of the British Ceramic Society by courtesy of the Council of that body. The author is Scientific Officer, Metallurgy Department, National Physical Laboratory.

† Trans. Ceramic Soc., 38, 341, 1939.

‡ *Ibid.*, 37, 353, 1938.

arranged like the first course except for small displacements which break the joints and also prevent the flame from impinging on the second course as it leaves the furnace. This arrangement avoids putting a serious bending moment on the bricks of the lower course spanning the furnace. The third course of light insulating bricks may be laid in any way which breaks the joints, provided that they are protected from the cutting action of the flame.

Starting the Furnace

When starting the furnace the burner, which has flexible connections for gas and air, is placed with its nozzle just outside the aperture provided, so that air, other than that passing into the burner, can reach the flame. (At this stage the burner is used with the secondary air supply cut off.) The gas and air supplies are then gradually increased, and after a time the secondary air supply to the burner is brought into action. When the furnace has become red hot, the burner nozzle is inserted in the aperture, and luted with a mixture of equal parts of clay and alumina made up with water to the consistency of mortar. Although the nozzle of the burner is of heat-resisting steel, it would overheat at the higher furnace temperatures but for the cooling effect of the cold gases passing through it. It is therefore necessary at the end of a heat either to reduce the gas and air consumption gradually or to remove the burner from the furnace.

It will be appreciated that the practicability of the very small exit from the furnace is associated with the high air pressure (70 lbs. per sq. in.) available. A larger area for the exit would be necessary if a burner using air at a normal low pressure were used. In such a case radiation losses could be minimised by building a tortuous passage for the issuing gases. It would then be necessary to make separate provision for sighting the pyrometer. Such arrangements should not be difficult; but the lower the air pressure available, the more difficult becomes the problem of securing adequate mixing of gas and air. The burner which is used for most purposes, and which is amply sufficient for the temperatures mentioned above, has a maximum gas consumption of about 600 cub. ft. per hour. A burner with a larger air jet has also been used, the maximum gas consumption being 1,100 cub. ft. per hour. Such a consumption is rarely required for a furnace of the size described, but when the full gas consumption is not used, the air pressure required for the second burner is naturally lower than for the first burner, although the reduction of pressure is not sufficient to impair the excellent mixing of gas and air.

Alumina containers are used to protect objects to be heated from direct contact with the flame. When the objects are not themselves alumina, such a container may also be necessary to prevent contamination of the furnace hearth which might result from overheating. After every heat it is desirable to inspect the furnace, and, if necessary, seal small cracks by applying with a brush the alumina slip already mentioned.

Finally, it may be remarked that a reasonable life may be expected from a furnace built carefully as described. If, however, rapid heating is specially desired, the thermal capacity of the furnace may be considerably diminished by a reduction of dimensions. It is practicable to employ an alumina lining ¼ in. thick surrounded by clay-alumina bricks 2 in. thick and then insulating bricks 3 in. thick. The quicker heating obtained in this way involves too great a sacrifice in the life of the furnace to be generally recommended. A small reduction of maximum temperature will, however, greatly extend the life of the furnace, and with careful attention to avoid accidental overheating such a design may be very useful.

Moulding a Bending Block Casting

By W. Gudgeon.

The casting shown in Fig. 1, although an apparently simple "flat-back" at first glance, nevertheless calls for experience and the exercise of caution during the different stages of moulding. The weight of the casting to be described was approximately 3 tons 17 cwts., the dimensions being 8 ft. by 4 ft. by 9½ in. thick, with core prints on the pattern to receive 100 cores, of which 96 were round, measuring 10 in. long and 1¼ in. dia., and four were slab cores, measuring 4 ft. by 1 ft. 8 in. by 2½ in. The slab cores broke through each side of the casting.

All the cores were made of oil sand consisting of 50 per cent. Lancashire red sand and 50 per cent. sea sand, with the introduction of a well-known proprietary brand of oil as the bonding medium. The advantage of this mixing lies in the fact that the sea sand imparts the necessary friability which facilitates the removal of the round cores when dressing the casting, while the red sand possesses the highly important property of withstanding the possible effects

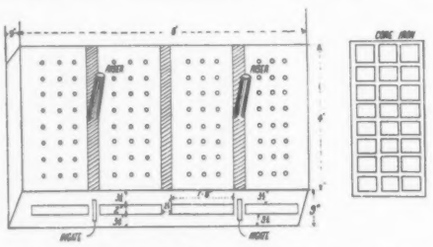


Fig. 1.—Bending Block Casting and Core Iron Employed.

of erosion brought about by the extreme heat of the molten iron.

A strong grid was used in making the slab cores. This prevents sagging in handling and, when it was placed in the prints, chaplets in the bottom part were rendered unnecessary. When making the slab cores, a layer of fine ashes was placed in them, these being visible at each end of the cores.

Mould Skin-Dried

A level bed was made to receive the pattern, the bed having been well vented down to a layer of coke with a ⅛-in. vent wire. Bearing irons were placed under the core prints to take the weight of the cores. The molten iron enters the mould by way of the two ribs shown in Fig. 1. The top part of the mould was closely gaggered, and as an additional precaution the surface was sprigged to prevent the possibility of "drawing down" of portions of the top part of the mould by the heat of the metal. The mould was skin-dried, and it was important to ensure that this was done thoroughly; otherwise "shell scabs" might have resulted, leaving unsightly dents on the casting when they were removed.

When the slab cores had been set in the prints, the round cores were inserted, passing through holes of the same size in the cores and into corresponding prints in the bottom of the mould. Each slab core was held down by four ⅛-in. chaplets, making sixteen in all, these being securely wedged after the job had been weighted. In a mould of such design, plenty of weight is required to hold down the top part, which is subject to tremendous pressure at the moment the mould becomes full of iron. In this case 10 tons was employed, the strain also being relieved by placing two risers, 5 in. dia., over the sections of metal as shown in the sketch above. The casting was fed down these two risers.

Distribution of Steel Supplies

DEPARTMENTS AND SERVICES COVERED

The new scheme for the distribution of steel supplies, details of which were given in our last issue, came into operation on April 1. All the consuming interests have for the purposes of the scheme been grouped under Government Departments which, in conjunction with the Iron and Steel Control, will be responsible for the supplies of finished steel to the services covered by the Departments.

The Departments, with the services covered by each of them and their distinguishing symbols, are given in Appendix B to the scheme, and we append the particulars.

APPENDIX B.

Departments, Symbols and Services Covered

Home Office (symbol H.O.)—Home Office services, *e.g.*, prisons, police, approved schools, etc.

Ministry of Home Security (A.R.P.)—Requirements for camouflage, screening blast furnaces, etc. Steel for A.R.P. (including Scotland).

Admiralty (Ad.)—Navy requirements. (Ad.M.)—Mercantile shipbuilding and repairs.

War Office (W.O.)—B.E.F. requirements, Army buildings, medical stores, fuel and light.

Ministry of Supply (M.S.)—All other requirements for Army. Machine tools, small tools and gauges. (F.)—French Government requirements, direct or indirect.

Air Ministry (A.M.)—Air Ministry requirements.

Scottish Departments (S.D.)—Schools, hospitals, housing schemes, police stations, prisons, special areas factories, agricultural buildings, land drainage works, piers, etc., water supplies, sewerage.

Board of Trade (B.T.(1))—(1) Gas Undertakings. (B.T.(2))—All Home Civil requirements except where specifically included under another Department. (B.T.(3))—Miscellaneous agricultural requirements other than agricultural machinery and buildings. (B.T.(4))—Indirect exports (*i.e.*, exports of finished goods), excluding requirements of B.E.F. and oil companies and French Government requirements. (B.T.(5))—Direct exports (*i.e.*, exports of finished steel as listed in Appendix "A") excluding requirements of B.E.F., India and oil companies and French Government requirements.

Board of Education (B.E.)—Schools.

Ministry of Health (M.H.)—Ministry of Health services, *e.g.*, hospitals and housing schemes, water supplies, sewerage.

Ministry of Agriculture and Fisheries (A.F.)—Agricultural machinery, including Scotland. Agricultural buildings and land drainage works, excluding Scotland.

Ministry of Transport (M.T.)—Railways (including all wagons used on railways), ports, canals, highways, tramways, works and buildings for Ministry undertakings, motor vehicles and trolley vehicles, gas producers for motor vehicles.

Ministry of Food (M.F.)—Provision of tins and packing material for food including food for service requirements. Food factories and buildings for storage and distribution.

Office of Works (O.W.)—Certain new factories and buildings and internal requirements therefor. Certain Government stores and equipment. Fire-fighting appliances.

General Post Office (P.O.)—Post Office requirements.

Mines Department (M.D.)—Requirements of all mines and quarries.

*Petroleum Department (P.D.)—Oil companies' requirements both home and export.

*Electricity Commissioners (E.C.)—Electricity supply industry covering generating stations, the Grid and distribution systems.

Northern Ireland (N.I.)—All public services for Northern Ireland.

*India (Ind.)—All finished steel for direct export.

* For the purpose of this scheme these are regarded as a Government Department.

Note.—"(B)" added to symbol of any Department represents allocations to Buildings.

Malleable Cast Iron

DISCUSSION OF MODERN DEVELOPMENTS

Members of the Birmingham, Coventry and West Midlands Branch of the Institute of British Foundrymen evinced keen interest in Mr. H. G. Hall's Paper on "Malleable Cast Iron" (printed in our March 21 and 28 issues). The discussion which followed its presentation threw additional light on some of the newer developments in the field of malleable.

The BRANCH-PRESIDENT (Mr. A. Tipper, M.Sc.), in thanking Mr. Hall for his excellent Paper, said that the preparation of such a Paper obviously meant considerable sacrifice, and for that reason the members were extremely grateful to him. Mr. Tipper said he had been particularly interested in the way Mr. Hall had described the sort of balance between the taking up of cementite by the austenite, and the breaking down of the austenite into ferrite and graphite. The author had also given a graphic picture of what went on under graphitisation and the decarburisation process.

Better Definition Needed

MR. G. R. SHOTTON thanked the lecturer for his comprehensive survey of the recent developments in malleable cast iron, but said he must take exception to one phrase in the definition of malleable iron. It was to the effect that malleable cast iron was a white iron free from primary graphite as cast in which part or all graphite was broken down by annealing. He thought the phrase "part or all" was too loose. By heating up for a few minutes and producing one speck of graphite, it became a malleable casting. He agreed with Mr. Hall's remarks concerning short-cycle malleable, but he did not think its development in this country was likely to succeed rapidly. When producing castings of various sections they could not force concentration close to the danger line, as the danger of getting primary graphite became great.

Mr. Hall's remarks concerning cyanide hardening were interesting. The same thing applied to whiteheart unless it was particularly good whiteheart initially. Although the process was very successful, it was only so when applied to particular types of work and under strict control. He had seen whiteheart castings that would break when dropped on the floor in the same way as blackheart castings would. In regard to pearlitic malleable, the author had said that the net shrinkage was less than normal blackheart, but although he did not know definitely he would have expected that the net shrinkage from the pattern size would have been greater.

Short-Cycle Malleable

MR. HALL, replying to Mr. Shotton, said that the definition of malleable iron he gave was actually the best he had seen. Mr. Shotton was correct in saying that the particular phrase "part or all graphite" was a little loose. He himself had a little difficulty in putting it clearly, but fundamentally he thought the definition was a sound one. In regard to short-cycle annealing, they semed to be much of the same opinion. If iron was decarburised to a depth of ¼ in. and then re-annealed, the austenite from the centre travelled towards the edge, and at the end of annealing the structure was fairly uniform from centre to edge. It reduced the carbon content to such an extent that complete graphitisation was rather difficult, but it did tend to point to the fact that reheating tended to even things out. He would suggest that pearlitic malleable could be successfully produced from inferior original malleable. That reaffirmed his idea that annealing could be carried on in a gas atmosphere, if that gas atmosphere could be controlled to produce decarburisation at will. Mr. Shotton was correct concerning the expansion of pearlitic malleable. What it was meant to convey was that in the final stage the casting would be slightly smaller than if made in blackheart iron.

Pearlitic Malleable

MR. A. J. SHORE wondered if Mr. Hall could indicate the scope of the application of pearlitic malleable. Would it be possible to use it in connection with hydraulic cylinders and rams, where high pressures were required, and how did it compare with steel castings both from the question of performance and price? Was it easier or more difficult to produce than steel castings? The surface finish of small steel castings was often criticised, and he wondered if a better finish could be obtained on such malleable.

MR. HALL said he had already suggested one way in which it could be used as a bearing metal. Its application originally was for brake-drums and gears, and also for castings in cement mills in place of steel castings. The finish generally was of a much higher order than that of steel castings. One particular advantage of pearlitic malleable made by reheating was that it allowed of freer machining and a final heat-treatment. After that final heat-treatment the metal would probably be too hard to machine. The obtaining of a certain degree of hardness was far more difficult than obtaining the same degree of hardness in steel, because there was a potential background over 2 per cent. of carbon to be dealt with. It was rather difficult to control thin and thick sections from that point of view. Thin sections produced a harder matrix than thick sections, and in the following quenching the thin section would be hardened far more than the thick section. It was not so easy, as it seemed to produce pearlitic malleable with a definite range of Brinell numbers, which was the only way of checking up hardness. There was so much surface decarburisation present that one might get a figure of 150 or 160 on the surface, while the body of the casting would be well over 200. Although its field of possibilities was enormous, the control necessary was very difficult, particularly in regard to castings weighing about a cwt. Then the quenching of heavy-section castings would, he was afraid, set up so many strains that it would be inadvisable.

Influence of Sulphur

MR. A. A. TIMMINS added his quota of praise of Mr. Hall for his clear definition of an interesting subject. It was difficult to offer criticism, but he did not think he sufficiently stressed the influence of sulphur on white malleable iron. That was one of the bugbears of the majority of whiteheart irons produced in this country. It probably dated back to the old days when malleable founders mostly used white pig-iron or a grey pig-iron which was cupola-melted material. High sulphur content was detrimental from an annealing point of view, but at the same time sulphur was a definite advantage to whiteheart malleable in that it prevented graphitisation while decarburisation proceeded.

That was an important point from the malleable point of view which did not arise in the case of blackheart iron, because there was better control in the melting furnace. In regard to short-cycle and pearlitic malleables, he had heard it said that there was no difference in the chemical properties of the short-cycle malleable and blackheart material, the only change being that the annealing cycle was shortened. He was somewhat surprised that Mr. Hall did not say more about the type of pearlitic iron known as Z-metal. In his opinion that was the type which was likely to be more rapidly developed than any other variety because of its good combination of strength, ductility and machinability.

MR. HALL said he was under the impression that he had stressed the influence of sulphur in the way that Mr. Timmins had indicated. He wondered why this country had not gone in more for the high-manganese type of whiteheart than for the sulphur type. A certain diffusion of sulphur took place under decarburising conditions, and Dr. Roll had indicated that that migration of sulphur actually formed big points of sulphur just under the surface which coincided with a layer of fine pearlite. From that he argued that there was a certain recarburisation taking place which gave a fine layer of pearlite. He agreed with Mr. Timmins that Z-metal was probably the most likely type of malleable to be developed. Short-cycle blackheart was as good as normal blackheart, providing there were no pearlite areas on the edge. In regard to short-cycle annealing, the chief difficulty was the use of high temperatures initially. One of the reasons why it was not popular in this country was that small quantity production with small batch-type ovens must be adopted, and the temperature kept up and held for a definite time.

Limit of Phosphorus Content

MR. J. BELL declared it was refreshing to hear a lecture on malleable iron without the author being biased in favour of whiteheart or blackheart iron. He was not quite clear whether 0.2 per cent. limit of phosphorus was permissible in whiteheart or in blackheart iron.

MR. HALL stated that 0.2 per cent. of phosphorus could be regarded as the limit, but, as he had indicated, there were certain dangers. In regard to cyanide hardening, he really did not see why it should not be applied to blackheart, providing it was sufficiently decarburised.

On the proposition of MR. BELL, seconded by MR. BOLTON, the lecturer was heartily thanked for his Paper.

Steel Consumption of Non-Producing Countries

Nations which must import all or most of their requirements of steel consumed nearly 12 million tons of finished steel products in 1937, it is estimated by the American Iron and Steel Institute. Steel consumption in those countries represented about one-eighth of the estimated total of 96 million tons of steel consumed throughout the world in that year, the latest for which full data are available. Almost 80 per cent. of the steel consumed in countries where little or no steel is made was imported from Great Britain, France, Germany and Belgium-Luxemburg. Ten per cent. came from the United States.

Those parts of the British Empire which produce no steel consumed almost one million tons in 1937, while South American countries consumed approximately 1,500,000 tons. The non-producing countries of Europe consumed nearly 2,500,000 tons. In addition, there are many other countries like Sweden, South Africa, Mexico and Canada, which produce some steel, but generally less than half as much as they require for consumption.

The countries which transact most of the world's steel export business accounted for about 77 per cent. of the total amount of steel produced. Russia, Italy and Japan, which export relatively little steel, produced about 20 per cent. of the total. Average steel consumption *per capita* in those important steel exporting nations, which have about 20 per cent. of the world's population, is 350 lbs. of steel per year. This is more than 12 times as much as the annual consumption of 28 lbs. *per capita* in nations which produce little or no steel.

Some Principles of the Enamelling of Cast Iron*

By G. T. O. MARTIN, Ph.D.

Vitreous enamelling is a very controversial subject and even long experience of the process does not lead to views in agreement with those of others. It is suggested that the following discussion of the effects of various factors in the process may lead to reconciliation of facts and observations which are often difficult to relate one to another.

It is proposed to confine the Paper to cast-iron enamelling. Although sheet steel enamelling has its difficulties, it is generally recognised that cast-iron enamelling introduces more possibilities of trouble, since cast iron is a more complicated and variable material. For convenience, it is proposed to consider the question under three headings: (1) Effect of the metal; (2) effect of the enamel, and (3) effect of the application process. This division is not a rigid one, as all three are to some extent interdependent, and successful enamelling usually depends on the striking of the correct balance between them. While the relation between the iron and the enamel has been discussed at great length on many occasions, the third factor has been given less (and in the opinion of many, insufficient) attention. It is encountered in its most accentuated form in the difficulty in reproducing laboratory results on a works scale.

The vitreous enamelling of cast iron gives rise to a number of possibilities of trouble arising, causing defects of various kinds. Consequently, articles on this subject generally consist chiefly of descriptions of faults and how to cure them. Since the causes of such faults are frequently well recognised, it would appear preferable to prevent them arising, by taking suitable precautions.

It is easy to look at the vitreous enamelling process too much "through production spectacles" and a more objective consideration of some of the fundamental principles involved may help to prevent, rather than cure, some of the troubles encountered in practice.

EFFECT OF THE CAST IRON

This can further be sub-divided into metal composition and structure, surface conditions and casting design, although these are not completely independent factors, as certain types of casting call for a particular metal composition for successful production in the foundry. The view that any sound clean grey iron casting can be enamelled is borne out to a large extent by the work done by jobbing enamellers, although the methods used and the standard of finish attained might not always be suitable for regular production work. Much has been published regarding the relation of enamelling troubles to the structure and composition of the metal. Most of the difficulties encountered through development inquiries have, however, in the past been connected with cupola melting conditions, bad design, running or gating, ladle conditions, or unsound, dirty or open-grained metal, or to mould conditions. It is perhaps advisable to add that for a high standard of finish and the use of resistant types of enamel, metal structure and casting design become important factors.

From the enameller's point of view, the requirements of a casting for enamelling are that it should be of uniform thickness, free from subcutaneous defects and from sand and facing materials burned into the surface, and of a composition and structure suitable for the enamel to be applied to it. With regard to this latter factor, the amount of latitude permissible depends to a large extent on the type of enamel and enamelling process used. It is not intended to discuss in detail the foundry practice required for production of castings of the above-mentioned properties, as it includes the precautions a conscientious foundryman would take in the production of grey iron castings for other purposes.

Useful Precautions

The majority of castings enamelled can be classified as light castings, that is, of fairly thin section. Quite a number of heavier castings are enamelled, but these are generally dealt with by specialist firms or fall into the hands of jobbing enamellers. They are frequently unsuitable for vitreous enamelling when judged by normal standards, and have to be given individual treatment, and are therefore outside the scope of a general discussion of cast-iron enamelling. Attention will therefore be confined to light castings. Normally these may be from $\frac{1}{8}$ to $\frac{1}{2}$ in. thick, the average thickness being from $\frac{3}{16}$ to $\frac{1}{4}$ in. The question of metal composition is largely decided from foundry considerations. Thus the phosphorus content must be sufficient for the molten iron to be fluid enough to fill completely the thinnest and most distant parts of the mould, usually being above 1 per cent. but not often above 1.5 per cent. High phosphorus content is often stated to be a cause of the cracking of castings on heating, and a maximum of 0.9 per cent. has been suggested. The silicon content must be sufficient to ensure that the castings are completely grey and free from chilled edges, etc., and is usually between 2.5 and 3.0 per cent., although successful results are in some cases obtained with silicon contents down to 2 per cent.

Under normal cupola melting conditions, the carbon content of this type of metal will be from 3.0 to 3.2 per cent., and in the castings about 0.4 to 0.5 per cent. will be present in the combined condition, although this will depend largely on the thickness of the casting, which influences the rate of cooling in the mould. A tendency to high combined carbon content, or a distinctly non-uniform combined carbon content, may give rise to warping and possibly cracking, when the castings are heated during annealing or enamel fusing. The breaking down of the combined carbon, present as iron carbide, to form graphite involves an expansion of the metal, and if this does not take place uniformly, warping or cracking may result. This tendency may be aggravated if elements which stabilise combined carbon, *e.g.*, chromium, are present, having been introduced from the scrap charged to the cupola. In this case, graphitisation takes place during both annealing and fusing, and as the latter is normally carried out at a temperature insufficient for straightening, permanent distortion may result. Castings should be almost free from combined carbon and straight after annealing, and should remain so after fusing if properly supported.

The remaining elements to be considered are sulphur and manganese. It is generally considered that the sulphur content should be kept below 0.1 per cent., although in many cases up to 0.15 per cent. sulphur is used without any trouble arising. The presence of sulphur favours the production of combined carbon and has been known to make the iron white in thin sections. Fortunately this effect is counteracted by the presence of manganese, the sulphur then being present as manganese sulphide instead of as iron sulphide, and it has been found as a result of experiment that for this purpose the manganese should be 1.7 times the sulphur content plus 0.3 per cent. Even if this condition be fulfilled, however, the presence of sulphides in the metal has been said to increase the tendency towards rusting, and in extreme cases may cause faulty adhesion of the enamel. A high sulphur content can arise from the use of too much or unsuitable scrap in the cupola charge, since all the sulphur present in the charge will appear in the melt. Also excessive sulphur content of the coke and insufficient limestone addition will cause pick-up of sulphur during melting and increase the total sulphur content of the metal.

Metal Structure

Turning to metal structure and its influence on the enamelling process, it can be said that there is little variation among comparable castings from different sources, since there is a general tendency towards the use of pig-irons of similar types, which has arisen as a result of experience. The best structure for enamelling is a ferrite-graphite one, with fine graphite and low combined carbon, and it is advisable that the structure should be stable to heat during the final enamel coat fusing. When "direct-process" enamel is to be applied by the wet process it is customary to ensure this by suitable heat-treatment known as annealing; in other processes the fusing of the ground coat accomplishes the same purpose. Any considerable change in structure during the final enamel fusing process can alter the thermal expansion coefficient of the iron, and may lead to reactions causing excessive gas evolution, with consequent bubble defects in the enamel. Fig. 1 shows the structure as cast, and Fig. 2 the structure of the same iron after annealing.

Gas Elimination

In all cast-iron enamelling, gas is given off from the base metal and passes through the enamel layer. In the ordinary way the enamel heals over again, and no trace remains of the bubbles and craters made by the gas during its passage through the enamel layer, but if the gas evolution should be excessive, or incomplete when the casting is cooled, or the enamel should be too viscous for free escape of the gases, bubbles and pinholes will remain in the enamel layer when it has solidified.

The above-mentioned preliminary heat-treatment assists in several ways, and for maximum benefit it should be carried out at a temperature somewhat above the enamel fusing temperature. In ground coat fusing, this is, of course, taken care of, but the importance is not always

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fully recognised in the case of direct wet-process enamelling. Firstly, light castings made in green sand may contain gases entrapped during cooling, and these are driven out during annealing or ground coat fusing, and thus will not cause trouble when the finish coat is fused. Secondly, the breaking down of combined carbon removes another source of gas which may be evolved during enamel fusing. A grey iron light casting made for enamelling is normally rather highly pearlitic, and may have an average combined carbon content of between 0.4 and 0.7 per cent. This is, however, reduced to less than 0.1 per cent. after suitable heat-treatment in the annealing or ground coat fusing. Castings to which enamel is to be applied directly must be practically free from combined carbon, as this reacts with the enamel to cause gas evolution, which gives rise to bubble defects unless the enamel be particularly fluid at fusing temperature.

Where a matt ground coat is used, annealing is often unnecessary, partly because the ground coat is free from oxides which would react with the combined carbon, and is in any case not

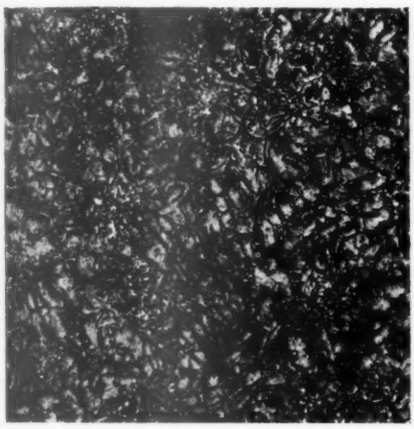

Fig. 1.—Structure of Cast Iron as Cast. × 100.

completely melted, but only sintered, so that it is doubtful whether bubble defects could occur, and partly because the ground coat fusing itself serves as an annealing process. In dry-process enamelling, where the ground coat is a true glaze, any gas evolved readily escapes through the thin enamel layer when the ground coat is fused. Thus, in all three cases the casting is substantially free from combined carbon before the finish coat is fused.

Silicon Content and Gas Evolution

If the silicon content of a grey cast iron be such that, at the enamelling temperature, the "critical point" resulting therefrom is higher, *i.e.*, at a temperature above which graphite can dissolve and diffuse in the solid iron to form more combined carbon, then this combined carbon can diffuse to the surface of the metal and react with the enamel, causing continuous gas evolution and impossibility of enamelling without defects. The silicon content used in practice is generally sufficient to avoid this difficulty. This comparatively high silicon content also usually prevents any chilled structure even in thin sections, although too much moisture in the sand is a factor which could produce this fault in borderline cases. Much discussion has taken place about the micro-chill which was stated by Krynitsky and Harrison to be present on the surface of grey iron castings, and to consist of a very thin layer containing carbide and difficult to remove by ordinary methods, such as shot-blasting. It was suggested that, on heating, the carbide in this layer breaks down to a sub-microscopic graphite which is readily oxidised by atmospheric oxygen, the CO and CO_2 produced causing bubble defects in the enamel. There is, however, no microscopic or other direct evidence of such a layer.

Most of the carbon is present in castings for enamelling in the form of graphite, and in the past there has been considerable discussion on the part played by graphite during the enamelling process. Experiments by Dr. Norbury showed that graphite can react with vitreous enamel, but the reaction soon ceases, since the two cannot diffuse into one another. It is actually possible to enamel a carbon plate without bubble defects. This is the most probable explanation of the "Manson effect,"[1] in which vigorous bubbling occurs at first when heated cast iron is dusted with a very thin coating of enamel, although no reaction occurs on applying more enamel and no bubble defects remain in the enamel. Combined carbon at the surface can also produce a similar effect, as described above. Dr. Norbury showed that graphite flakes would give rise to trouble by this means only if they were sufficiently large. By casting a slab of cast iron against a chill and taking suitable sections, specimens were obtained in which the graphite size increased continuously from one end to the other, and it was found that the parts farther from the chill, having the coarser structure, showed increasing amounts of boiling, while on those near the chill no defects were produced. The boiling defects appeared quite sharply at a given graphite size, depending on the type of enamel. It is probable that the gas bubbles formed by the small graphite flakes were too small to coalesce, while those from the larger flakes could coalesce and form bubbles sufficiently large to produce visible blisters.

Atmospheric Oxidation of Graphite

It is unlikely that sufficient gas to produce the defects encountered in practice arises from reaction of graphite with enamel. Another possibility of gas production is oxidation of the graphite by atmospheric oxygen. Angus[2] points out that this could only occur at temperatures above 680 deg. C.; below this only the iron would be oxidised. Most cast-iron enamels are sufficiently fluid at this temperature to be almost impermeable to gases so that this reaction could occur only to a limited extent. The dried coating of wet-process enamel, known as biscuit, protects the iron to a large extent, and once a ground coat has been fused on to the iron, access of oxygen is limited or impossible. A more probable explanation of the gas evolution during enamel fusing is a reaction between graphite and iron oxide, produced by absorption of oxygen into the surface during cooling in the mould, during annealing prior to blasting, or during the early stages of the enamel fusing process. This is more likely to occur where the metal has a coarse or porous structure, and it is found in practice that gas-bubble defects frequently occur where the castings have been gated, particularly if such castings have been stored for some time.

Enamelling defects due directly to metal composition or structure generally occur almost all over the casting. In practice this is a rare fault, as defects are usually confined to one or two places. Typical examples of gas defects over a large part of a casting are those due to too coarse a graphite structure, caused by excessive thickness of the casting, or the use of unsuitable pig-iron in the cupola charge. Certain titanium-bearing pig-irons are helpful in obtaining a fine graphite structure. In dry-process enamelling the metal composition has some influence on the thermal expansion, and should be kept reasonably constant if troubles from crazing and chipping are to be avoided. The difficulty in devising any systematic relation between metal composition and expansion coefficient has been pointed out by Black.[3]

Surface Condition

What might be called surface condition plays a very great part in cast-iron enamelling. This term includes the characteristic properties of the surface of the casting as it comes from the mould, the presence of surface and subcutaneous defects, and effects produced in preparing the casting for enamelling. Considering first the raw casting, it is the custom in most light castings foundries to devote attention to the production of a smooth surface on the castings, but this does not necessarily ensure the production of a sound surface, and most enamellers prefer to judge the quality of the castings after they have been blasted, which removes the surface layer and exposes any subcutaneous defects.

This smooth skin is produced by means of facing compounds, and by the use of coal dust in the moulding sand. This use of coal dust in the facing sand is almost universal, and it seems generally agreed that it has no ill-effects on the enamelling, provided that it is not used excessively (about 4.0 to 5.0 per cent. is normal). In many cases facing compounds can be dis-

Fig. 2.—Structure of the Cast Iron shown in Fig. 1, but after Annealing. × 100.

pensed with when coal dust is used in this way, but for castings with large surfaces, such as baths, a separate facing compound is generally used. Much has been written about the ill-effects produced by such facing compounds, but many are used successfully in practice, including blackings consisting of mixtures of ground coke, anthracite or charcoal with a small amount of plumbago. Castings ¼ in. thick or thinner give no trouble with such facing compounds, but thicker castings, due to the slower cooling, tend to burn them into the skin, making them difficult to remove by blasting with sand or chilled iron, even after annealing.

If no facing compound be used, the sand must be sufficiently refractory not to be burned into the casting, as this is one of the worst faults to be encountered in enamelling, especially in direct wet-process enamelling. It causes gas evolution on heating due to the presence of associated surface or subcutaneous defects, and from clay and coal dust coating the sand grains. The sand grains can often actually be seen in microscopic examination or even simple visual examination of the surface (Fig. 3). Associated with the sand grains there may be holes in the casting which are often only revealed after a thorough blasting. If these holes are freely open to the outside of the casting, they are cleaned out by the blasting process and are less likely to give rise to defects. These holes can generally be filled with a refractory enamel composition. Holes which are only connected to the surface by a small aperture are more likely to cause defects, as they cannot be cleaned out or filled.

A similar effect occurs with what can be called subcutaneous oxidised defects (Fig. 4). Sometimes the surface of a casting will contain just one or two such defects, giving rise to large isolated pinholes or crops of pinholes in the enamel, while sometimes considerable areas of the casting are "porous" and "spongy," and defects will occur over various parts of the casting. Such unsoundness can be brought about by pouring too-cold metal, whilst lack of permeability of sand can cause gasholes or blowholes. It seems unlikely that gas defects in the enamel can be caused simply by evolution of the gas filling such spaces, and it is more probable that the gas comes from reaction of iron oxide in these spaces with the carbon in the metal or facing compound or coal dust from the mould. This type of defect is less likely to be completely uncovered when the casting is blasted, and thus cannot be cleaned out and filled. Such defects are often not uncovered by the lighter blasting or even scouring with stone and water which is used for dry-process enamelling, but such cleaning methods are less effective in removing facing compounds from the surface than the more thorough blasting used before wet-process enamelling.

Enamel Adherence

So far the question of adherence of enamel to the iron has not been mentioned. McNair[4] has

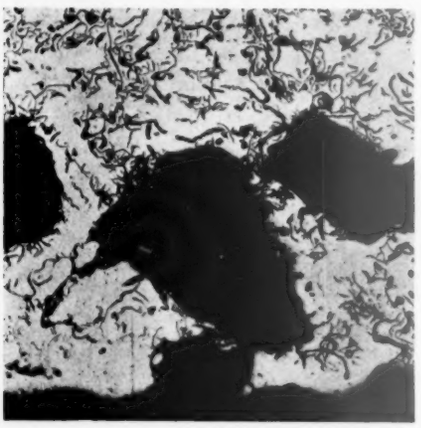

Fig. 3.—Sand Defect on Surface of Iron Casting. × 100.

described a number of experiments to test the adherence of enamel to castings made in different sands, with different facing compounds, and subjected to different surface preparation. The most important factor affecting the adherence was found to be the amount of blasting the casting received, while annealing did not improve the adherence, except when the castings had become rusty through prolonged storage. This appears to be in agreement with results found in practice. In connection with the effect of rusting on enamel adherence, it has been found that a superficial rusting can be satisfactorily removed by thorough blasting, but when rust has penetrated into the pores of the metal, gas bubble defects and poor adherence of the enamel result, unless prolonged annealing is carried out. Where a matt ground coat is used for wet-process enamel, it may become detached from the metal when the cover coat is fused. A possible explanation of this is the further gas evolution which will result from reaction between graphite flakes and the iron oxide surrounding them. Direct application of enamel to such a surface would be spoiled by gas bubble defects even if satisfactory adherence resulted. Adherence of enamel to cast iron can more conveniently be discussed with properties of the enamel.

The surface treatment of cast iron before enamelling can affect the adherence of enamel to the metal and the freedom or otherwise from defects. When the surface is only stoned and not blasted, the surface is not roughened and the relation between expansion coefficients of iron and enamel for satisfactory adherence becomes more critical. Filing and buffing produce harmful effects on the adherence, unless blasting is afterwards carried out. Scratch-brushing can be a satisfactory method of cleaning the casting surface, provided that no rusting has been allowed to occur. It is sometimes necessary to grind the surface of a casting to remove surface faults such as rat-tails, but this is generally followed by blasting in the usual way.

Laboratory experiments have shown that when the graphite structure is coarse it may be impossible to apply enamel directly to the iron without gas bubble defects being produced, but if blasting is replaced by honing or rubbing with emery paper, practically no defects appear. This is explained by assuming that the blasting burnishes over the surface graphite and delays its reaction with the enamel until the later stages of the fusing process, when it is uncovered and reacts to produce gas which causes the bubble defects. Removal of the surface layer of the casting undoubtedly improves the chance of successful enamelling, but whether this is due to the removal of "micro-chill" is rather doubtful. Krynitsky and Harrison,[5] and later Poste,[6] showed that machining a thin layer from the surface of a casting reduced the tendency of the enamel to blister, but the above-mentioned experiments show that the method used to clean the surface is also a factor, even on surfaces obtained by sectioning a casting, and which have never been in contact with the mould.

Design

The design of castings for vitreous enamelling has been widely discussed and certain principles are well recognised. When designing a new article, it is generally possible to observe most of these precautions, but unfortunately many castings were not designed with enamelling in view and simple alterations which would assist the enameller considerably are only carried out in exceptional cases. Probably the most important feature of the design of castings for enamelling is uniform thickness. This should not be taken too literally as small differences are difficult to avoid. If possible, there should not be more than a 50 per cent. increase or decrease from the average thickness. This is seldom achieved in practice, but the reasons for some of the thickness variations noticed are somewhat obscure.

Uniform section ensures even heating up in the furnace, and a design of balanced proportions is also helpful in this connection. Edges tend to heat up more rapidly than the body of the casting, and it is a good plan to thicken them suitably to compensate for this. Uniform heating-up ensures that the enamel is fused all over the casting at the same rate. Non-uniform section may lead to warping and cracking during annealing or enamel fusing, hairlining of the enamel or even crazing and chipping of dry-process enamel. Perhaps the worst types of thickness variation are the sudden changes produced by strengthening ribs or webs and by bosses or lugs. In all these cases the thickness differences should be kept down to a minimum to ensure soundness in the casting, and to avoid gas bubble defects, particularly when directly applied wet-process enamel is used. Lugs and bosses can generally be cored out, while chills in the mould have been found to reduce blistering troubles at such places, by prevention of porosity and coarse graphite structures. Angus[3] has pointed out that this indicates that blistering is due only to porosity or graphite formation. If this is the case then the thickness as such can only produce defects due to underfiring.

Another important point in the design of castings for enamelling is the absence of any sharp corners or edges. A minimum radius of $\frac{3}{16}$ in. has been recommended. A sharp edge will tend to show through the enamel, which usually forms a round edge when fused. It is sometimes stated that sharp edges can be satisfactorily covered with dry-process enamel; this is presumably due to the greater thickness applied. There is always, however, a tendency for enamel on sharp edges to chip very easily when subjected to shock.

Another consideration in the design of castings for enamelling is the avoidance as far as possible of large unbroken flat surfaces, as these will show up the slightest defect. Gates should be placed at the edges of castings and not on flat surfaces, to avoid washing of the mould; and the face side, or more important side, should be cast downward since any impurities will rise to the upper surface.

Effect of the Enamel

There are three methods of enamelling cast iron in general use in this country to-day. They are (1) single or double coat direct wet-process application, (2) wet-process application of a matt ground coat and one or more cover coats, and (3) dry-process application, generally over a ground coat applied by the wet process. The different types of enamels used have different properties and require different treatment, both in preparation and application, and each type has its own advantages and disad-

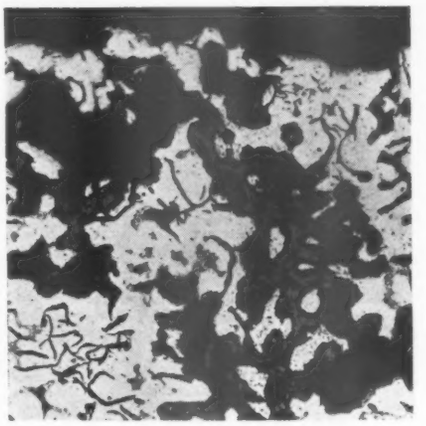

Fig. 4.—Subcutaneous Oxidised Defect. × 100.

vantages, and special difficulties and liability to defects. Moreover the methods used in the preparation of the enamel affect the behaviour during the application process, the quality of the finish obtained, and its behaviour in service, while the methods adopted in the application process can determine whether the greatest advantage is obtained from the properties of the enamel.

The "workability" of an enamel is the ease with which it can be applied without troubles arising, and depends chiefly on the physical properties of the enamel, both in the solid and liquid state. These in turn depend on the chemical composition of the enamel frit and the mill additions. Generally it is not possible to obtain all the desired properties in one enamel, and a compromise is necessary. The workability of enamels is also related to the quality and preparation of the base metal, and less workable enamels are more critical in this respect.

The chief property with which the enameller is first concerned is what is known as "hardness," that is, the refractoriness of the enamel, or the effort required to fuse it to a smooth and generally glossy layer. This will depend on its chemical composition; a higher content of refractories, such as silica, generally means that a higher temperature is required to fuse the enamel, while fluxes such as borax have the

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opposite effect. Every enamel has a certain "fusing range," characterised by the limits of temperature between which it can be satisfactorily fused on to the metal. The temperature used will also affect the time required.

Except for matt enamels, enamels are left in the furnace until they have attained a smooth glossy surface, although dry-process enamels will reach this condition on the hot casting outside the furnace at the beginning of the dusting period. Wet-process enamel applied directly may be fused at temperatures ranging from 720 to 760 deg. C., matt ground coat at about 800 to 820 deg. C., and dry-process enamels at temperatures between 780 and 850 deg. C., depending on the type of enamel. These figures refer to the temperature attained by the enamel. In wet-process enamelling, the load of castings generally remains in the fusing furnace sufficiently long to attain its temperature, which is recorded by a pyrometer. In the dry-process enamelling of large articles such as baths, the casting and enamel do not attain the temperature of the furnace, but are withdrawn when visual judgment indicates that the enamel is correctly fused and control of the furnace temperature is less critical.

Fluidity of Enamels During Processing

The gas which is always evolved during the fusing of vitreous enamel on to cast iron must pass through the molten enamel layer, which must then heal up again to leave no trace. For this purpose it must be fluid enough to allow the gas bubbles to escape readily, otherwise on cooling, blisters will remain where the gas bubbles have broken, but the enamel has not been able to flow back again. The viscosity of the molten enamel at any given temperature depends on its chemical composition, and enamels which for correct fusing require the same temperature may differ in viscosity and hence in their liability to form gas bubble defects.

Thus some acid-resisting enamels are fused at the same temperature as non-acid-resisting enamels, but are more viscous and difficult to work, requiring the cast iron on which they are applied to be specially free from surface defects and coarse graphite structure. Enamels containing lead are more easily worked than leadless enamels, since lead oxide gives a high degree of fluidity to the enamel. Boric oxide also improves the workability of an enamel, while barium carbonate has been used to replace lead oxide as it acts in a similar manner. Measurements of the viscosity of molten enamel frits at the U.S. Bureau of Standards' support the conclusions drawn from practical observation. Measurements made on sheet steel enamels in this country have been described by H. G. Abbott,[8] and show that an acid-resisting enamel is more viscous at a given temperature than a non-acid-resisting type.

Elasticity of Enamels

Elasticity is that property which enables a stressed material to return to its original shape and dimensions when the stress is removed, and the modulus of elasticity is defined as the force per unit area which would stretch a specimen of the material to twice its original length, although in the case of enamels this could not actually occur in practice without breaking of the enamel. The elastic limit of a material is that stress beyond which the specimen will not return to its original dimensions on removal of the stress. Since with a brittle material like vitreous enamel or glass at ordinary temperature, this point would be the breaking point, the breaking stress has a greater significance for enamels than the modulus of elasticity.

The modulus of elasticity has been determined experimentally and calculated from factors, but it is difficult to interpret the figures in terms of resistance to failure of the enamel by stresses arising during the enamelling or subsequently applied to the finished enamel layer. In considering the breaking stress, that is, the stress that is required to cause failure of the enamel, there are three properties concerned, tensile strength, compressive strength and modulus of rupture or transverse breaking strength. An enamel has a greater resistance to compression than to tension, and is normally in a state of slight compression when in a layer fused on to the metal.

An unsuitable relation between the thermal expansion coefficient of iron and enamel may lead to a state of tension either all over the casting or more probably in a few places where stresses are greatest. Stresses arising from uneven section of the casting may also place the enamel in tension, which will generally result in crazing of dry-process enamel. If the adherence is at all faulty, the enamel may chip off readily. Conversely, if the enamel should be placed in too great a compression, chipping may occur, which is also aggravated by poor adherence. Similar failures can occur in use of the enamelled article, if it is subjected to large and sudden temperature changes, involving uneven heating and cooling.

How Service Failures Occur

Failure of cast-iron enamel in service due to bending stresses is unlikely, owing to the rigidity of a casting compared with a piece of sheet steel. The usual form of failure is due to sudden impact, which produces a momentary deformation of the casting sufficient to stress the enamel past its breaking point. This will cause cracks to appear in the enamel, while if the adherence force is also neutralised and exceeded the enamel will become detached from the metal. Such a blow applied to the enamel produces both tensile and compressive stresses at the opposite sides of the enamel layer, when the metal deforms and when it returns to its original form.

The property of an enamel most related to this type of stress is the transverse breaking strength or modulus of rupture, which involves a combination of compressive and tensile stresses. It is found in practice that a thin layer of enamel is more durable and shock-resisting than a thick one. A thin layer of enamel will contain fewer residual stresses within the enamel layer itself, and also will actually have greater strength. It has been found that the tensile strength of glass fibres increases greatly as the cross-sectional area decreases. Thus a thin layer of enamel applied directly to the iron has the best resistance to impact. The thicker layer of enamel used in the dry-process has a somewhat smaller impact resistance than the thin layer used in direct wet-process enamelling. The use of a matt ground coat reduces the impact resistance since, due to the comparatively inelastic ground coat, the cover-coat enamel can be deformed by a force insufficient to cause deformation of the metal. This cushioning effect of the ground coat between cover coat and metal is, however, an advantage when thermal stresses are encountered, and castings enamelled in this way possess considerably greater resistance to thermal shock, such as produced by strong heating and cooling.

(To be continued.)

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[6] Bulletin of the American Ceramic Society, 1932, vol. 15, August, pp. 201–213. Journal of the American Ceramic Society, 1933, vol. 16, June, pp. 277–292.
[7] Journal of Research of the National Bureau of Standards, 1938, vol. 20, January, pp. 39–55.
[8] FOUNDRY TRADE JOURNAL, 1939, vol. 61, June 1, pp. 445–447.

Steel Supplies for Export of Manufactured Goods

As from April 1, under the new scheme for the distribution of steel supplies, the Board of Trade becomes responsible, in consultation with the Iron and Steel Control, for the allocation of steel required for the manufacture of goods for export. The issue of steel will be greatly facilitated and delay will be avoided where an export group is established for a particular trade. Satisfactory arrangements have been made with the Board of Trade for the administration by the group itself of a global allocation of material in substitution for the present system of individual applications for licences to the Iron and Steel Control.

While it is recognised that the April-June quarter must be regarded as a transitional period for the purpose of operating the new scheme, the Board of Trade consider it necessary to warn manufacturers that it is their intention that after the end of June the steel allocation for the export of manufactured goods should, in the national interest, be distributed through Export Groups, and that they will find it progressively more difficult to justify release of material to firms not so organised. It is therefore very important that manufacturers should join such groups as soon as possible and that the groups should have allocations arranged with the Board of Trade well before that date.

For the period April-June, licences for steel required for the manufacture of goods for export which are not yet covered by special arrangements with organised groups will continue to be issued by the Iron and Steel Control, to whom applications should be submitted direct, but as soon as a group is ready with its total requirements contact will at once be made with the Board of Trade, even within the period April-June.

Export Groups in the Steel and Engineering Industries

Export groups have already been set up in 19 industries, according to a statement issued by Sir Andrew Duncan, President of the Board of Trade. The following list gives the names and addresses of the secretaries of groups which have been set up in the iron and steel and engineering industries:—

Black Bolt and Nut Export Group.—Mr. E. L. Heathcote, 25, Bennetts Hill, Birmingham, 2.

Bright Bolt and Nut Manufacturers' Export Group.—Mr. E. L. Heathcote, 25, Bennetts Hill, Birmingham, 2.

British Metal Window Manufacturers' Export Group.—Mr. A. L. Hunking, 21, Tothill Street, London, S.W.1.

Cutlery Export Group.—Mr. A. H. Plews, Norris Deaking Building, King Street, Sheffield.

Edge Tools Manufacturers' Export Group.—Mr. N. Hodkinson, Chamber of Commerce, Birmingham.

British Electrical and Allied Manufacturers' Association. Electrical Machinery Export Committee.—Mr. Seaman, 36, Kingsway, London, W.C.2.

Compressed Air Machinery Export Group.—Mr. E. Lacy-Hulbert, Boreas Works, Beddington, Croydon.

Internal-Combustion Engine War Export Group.—Mr. Herbert Cowper, 32, Victoria Street, London, S.W.1.

Telephone and Telegraph Apparatus Export Group.—Mr. T. F. Lee, Connaught House, Aldwych, London, W.C.2.

Non-Ferrous Metals (Wrought) Export Group.—Squiers & Company, 115, Colmore Row, Birmingham, 3.

Hundred per cent. Sintered-Ore Charges

In "Teori. prakt. met.," S. L. KOPTEWSKI and his collaborators describe observations on the running of a blast furnace with a charge consisting of 100 per cent. of sintered ore. Experiments showed that only a sintered product of very high quality was suitable and that great care must be taken in obtaining a uniform composition. The best conditions of smelting and optimum properties in the product are obtained with 19 to 23 per cent. FeO in the sinter.

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- Forge Fans
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- "Sirocco" Centrifugal Fans, Dust Fans Reversible Propeller Fans
- A.R.P. Ventilating Units
- "Sirocco" and "Siroccofin" Air Heaters
- "Davidson" Dust and Flue Dust Collectors
- "Sirocco" Pneumatic Conveyance Plant

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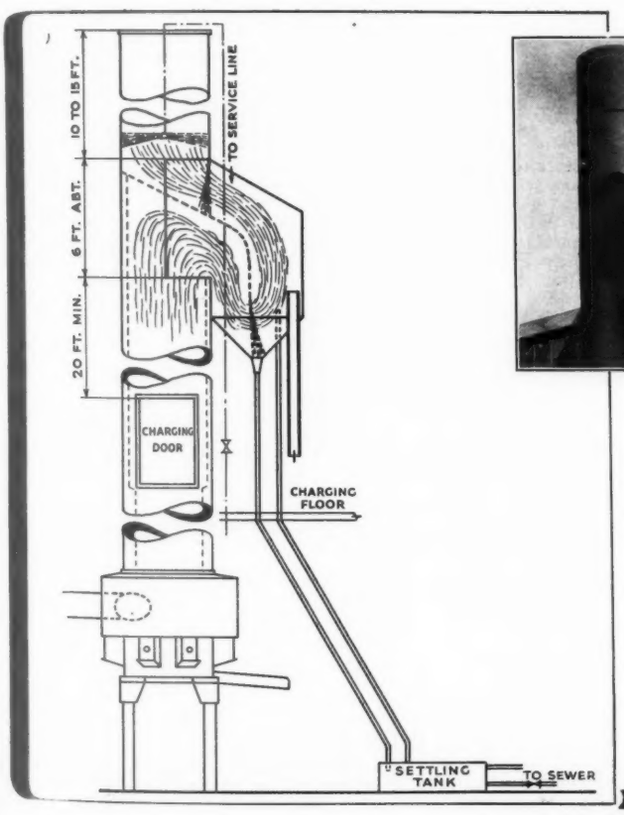

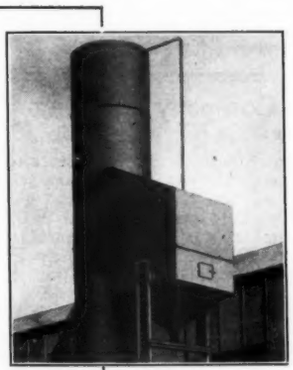

How the

W-W CUPOLA GAS CLEANER

PATENT APPLIED FOR

does its work

The construction of the Whessoe-Whiting Cupola Gas Cleaner can be seen from the drawing. Briefly, it consists of a steel chamber which is riveted or welded to the stack, and a baffle or deflector plate which diverts the gases into this chamber.

A spray nozzle is inserted in the stack just above the cleaner assembly and is connected to water mains. Water is uniformly discharged from the spray nozzle across the stack as coarse spray. The spray water runs off the main wall of the stack immediately above the chamber and a curtain of water is formed which drops on to the deflector plate. The gases are thus cleaned by direction change and thorough washing.

Upwards of 95% of grit together with most of the smoke and fumes are removed and stack glare is eliminated.

WHESSOE

Advertisement of The Whessoe Foundry & Engineering Co. Ltd., of Darlington

The Week's News in Brief

Trade Talk

A. B. Bofors, the leading Swedish armaments firm, made a profit of 18,220,000 Sw. cr. in 1939, which is roughly double the profit made in 1938.

The British Oxygen Company, Limited, is making a bonus issue of ordinary shares in the proportion of £1 to every £5 of stock held. For this purpose it is proposed to capitalise £576,850 of the reserve.

A 64-year-old employee, Mr. Archibald Blair, collapsed and died in the Bonnybridge Foundry of Smith & Wellstood, Limited, last week. He was found lying on the floor of the pattern store, where he had been employed for the past six years.

At a meeting of the joint board of the South Wales Siemens Steel Trade, held at Swansea, agreement was reached to raise the gross earnings of general labourers to £3 a week, an increase of 1s. 10d., with necessary consequential adjustments in the earnings of the grades immediately above and below that figure.

Recent reports indicate that the Egyptian Government is considering the establishment of iron and steel plant near Cairo capable of producing 120,000 tons of rolled steel annually, mainly merchant bars, and medium and small sections. It is believed, if the necessary equipment and machinery can be secured promptly and at prices not too far above those obtainable prior to the outbreak of war, that the contract for the erection of this mill will be placed with an American concern.

The Board of Trade announce that until further notice no application will be considered for licences authorising the importation of the following commodities from foreign countries other than France: Accumulators and parts thereof; baths, iron and steel; bell apparatus, electrical; bell domes and bell gongs; blast-furnace slag; latches, hasps, bolts, hinges, locks and keys, parts thereof and blanks therefor. The announcement does not apply to goods to be imported for re-export or for use in the export trade.

John Dale Metal Containers, Limited, Brunswick Park Road, New Southgate, London, N.11, have by special arrangement with J. Stone & Company, Limited, Deptford, been appointed exclusive licencees for the manufacture, sales and distribution of their well-known Ceralumin casting ingots. This group of aluminium alloys is covered by Air Ministry specifications DTD.250, DTD.255 and DTD.287. Their foundry department has been extended and re-equipped to take care of this additional output.

Workmen have begun dismantling the 50,000-ton former German liner "Bismark." Her metal will be turned into ships and munitions to prosecute the war against her former owners. The "Bismark," taken over by Britain at the end of the last war, became the White Star liner "Majestic." A few years ago the Admiralty purchased her for a training ship, and she was renamed H.M.S. "Caledonia." Over £300,000 was spent on her equipment. She was recently damaged by fire, and has now been sold to Thos. W. Ward, Limited.

The salving as scrap of the scuttled "Graf Spee" will apparently bring the Uruguayan shipbreakers face to face with many practical difficulties. The firm of Regusci & Voulminot, leading marine engineers at Montevideo, have received the contract for breaking up the vessel. Local divers have no experience of cutting metal underwater with oxy-acetylene apparatus and it is doubtful whether the necessary equipment is available locally. The wreck must be reduced to sections not exceeding 80 tons in weight, as the lifting capacity of the largest local floating crane is this figure. Under Uruguayan marine law, foreign craft and equipment must not be used for breaking up vessels in Uruguayan waters.

Speaking in the House of Commons recently, Mr. V. Adams asked at what price per ton the Ministry of Supply purchased raw aluminium. Col. Llewellin, Parliamentary Secretary, Ministry of Supply, replied that the Minister was buying the entire output of raw aluminium of the British Aluminium Company at prices varying with quality and form, but based on the pre-war price of £94 a ton for ingot aluminium. He was also buying aluminium from various countries abroad, and their selling price of £110 a ton was calculated to ensure that no loss was involved in the transactions as a whole. Any profit made on the sale of the aluminium went to the Treasury and in no way to the Control.

New Companies

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

D. D. Engineering, Limited—Capital £10,000. Mechanical, electrical, aeronautical and general engineers, etc. Subscriber: G. A. Smith, 2, Arbuthnot Lane, Bexley, Kent.

California Engineering Company, Limited—Capital £10,000. General engineers, etc. Directors: S. Taylor, Boverley, Ringley Road, Whitefield, Lancs; and T. Grimshaw.

Marco Conveyor & Engineering Company, Limited, Rowin Works, Lynn Road, Leytonstone, London, E.11—Capital £10,000. Directors: J. W. Wilkins, T. A. Richardson, T. A. Hammersley, R. H. Willard and S. R. Vincent.

Personal

Mr. Fred Clements, managing director of the Park Gate Iron & Steel Company, Limited, has been made a Vice-President of the Iron and Steel Institute.

Mr. W. Wood has retired from the position of works manager of the National Gas & Oil Engine Company, Limited, Ashton-under-Lyne, after 54 years' service with the firm.

Mr. W. Jenkins, of Hutchinson Place, Halfway, Cambuslang, for 20 years foundry foreman at Hallside Steelworks and later at Parkhead Forge, Glasgow, celebrated his golden wedding last Thursday.

Sir Harold Carpenter, Professor of Metallurgy in the Royal School of Mines, London, has been awarded the Honda Prize by the Japan Metallurgical Society. He is the first foreigner to receive the award—a gold cup and £300.

Wills

Macpherson, W. G., of Glasgow, retired steel merchant	£34,388
Spence-Thomas, Hubert, of Melingriffith, tinplate manufacturer ...	£52,110
Drake, J. W., of Halifax, formerly chairman and managing director of Drakes, Limited, gas engineers and ironfounders	£27,826

Company Meeting

Radiation, Limited

Radiation, Limited, the cooking and heating appliance manufacturers, have successfully turned over part of their manufacturing facilities to specialised work in connection with wartime activities, it was reported at the annual meeting in London. Sir C. Herbert Smith (chairman) said that following the declaration of war the special terms and facilities which gas companies had been in the habit of allowing to consumers purchasing gas apparatus had to be withdrawn and the domestic building trade practically stopped. The immediate effect was a considerable falling-off in the demand for their standard products, so that immediately the normal working of their factories was disorganised. Steps were taken at once, however, to turn their activities over to emergency work, so that the whole of the organisation should be made available for satisfying the country's immediate needs, and the possibility explored of making a variety of goods necessary for the prosecution of the war. New types of cast iron were required, and they had made available "Radiron," which was supplied in three different grades for a variety of purposes. The change-over from the making of light castings to the production of engineering castings had been duly effected. The capacity of their various foundries already amounted to a very large tonnage of castings each week, but if required the normal production could be considerably increased. The activities of their machine shops and their metal-working shops had been extended to enable them to deal with classes of work widely differing from those handled during their normal activities. They had emergency work on hand and, although such orders had increased steadily, they were hoping that their organisation would be called upon to render the much greater service of which they were capable.

Contracts Open

Chelmsford, April 8—Supply and erection of two cast-iron luteless oxide purifiers, for the Town Council. The Gas Engineer, Gasworks, Chelmsford.

Glasgow, April 9—Cable (v.i.r.), bolts and nuts, iron and steel castings, iron and steel bars, plates, galvanised steel wire, whin metal and chips for up to 12 months, for the Corporation Transport Department. The General Manager, 46, Bath Street, Glasgow, C.2.

Huntingdon, April 19—Provision and laying of about 12 miles of 3-in. to 6-in. spun-iron water main, with cast-iron specials, for the Rural District Council. Pick, Everard, Keay & Gimson, engineers, 6, Millstone Lane, Leicester. (Fee £4 4s., returnable.)

Reports and Dividends

Blythe Colour Works, Limited—Net profit for 1939, £38,831; dividend of 20 per cent.

A. Reyrolle & Company, Limited—Final ordinary dividend of 7½ per cent., making 12½ per cent. for 1939.

Vulcan Foundry, Limited—Net profit for 1939, £48,172; dividend of 5 per cent. on the ordinary shares.

Manganese Bronze & Brass Company, Limited—Net profit, £88,824; final dividend on the ordinary shares of 50 per cent., making 75 per cent. for 1939.

Vickers-Armstrongs, Limited—Profit for the year ended December 31 last of £1,778,143, after providing for contingencies and for income tax, E.P.T. and N.D.C., and after deducting expenditure on A.R.P.

C. Akrill & Company, Limited—Profit for 1939, £9,884; brought in, £21,081; preference dividend, £782; dividend of 3s. a share, £4,266; to taxation reserve, £2,000; to special development reserve, £6,000; carried forward, £17,917.

Hadfields, Limited—Trading profit for 1939, £302,210; debenture interest and profit and loss items, £37,912; net profit, £264,298; brought in, £384,033; preference dividend, £8,775; interim dividend of 7½ per cent. on the ordinary shares, £58,628; final dividend of 1s. 6d. per share (15 per cent.), £105,126; carried forwad, £475,802.

British Oxygen Company, Limited—Consolidated gross profit for 1939, £1,387,995; brought in, £48,007; depreciation, £422,053; taxation, £338,262; retained by the subsidiary companies for special appropriations and reserves, £99,292; preference dividends, £55,578; ordinary dividend of 17 per cent.; to reserve, £61,850; to tax reserve, £100,000; carried forward, £40,258.

Gibbons (Dudley), Limited—Net profit for 1939, after providing for taxation and depreciation, £28,026; brought in, £12,160; 7 per cent. preference dividend, free of tax, £2,100; dividend of 10 per cent. on the ordinary shares, £8,693; bonus of 2½ per cent. on the ordinary shares, £2,173; part of cost of modernising works written off, £4,000; to dividend equalisation fund, £2,500; to reserve fund, £5,000; carried forward, £15,019.

Obituary

Mr. Herbert Guedalla, who died at his home in London last week, aged 65, was a director of the United Steel Companies, Limited.

Forthcoming Events

APRIL 12.

Keighley Association of Engineers:—Annual dinner, at the Victoria Hotel, Keighley, at 6.45 p.m.

Institute of Vitreous Enamellers

APRIL 6.

Southern Section:—Exhibition meeting at Charing Cross Hotel, London, W.C.2, commencing at 2.15 p.m. At 2.30 p.m., introductory talk by H. M. Hibberd; 2.45 p.m., exhibition of products, apparatus and enamelling problems of special local interest; 4 p.m., tea; 4.30 p.m., "Manufacture of Frit and the Enamelling of Bronze and Precious Metals." Paper by W. E. Charles, illustrated by colour film; 6 p.m., close of meeting.

Institute of British Foundrymen

APRIL 11.

London Branch:—Joint meeting with Institute of Metals (London Section). "Heat-Treatment of Castings." Paper by H. E. Warrington at Caxton Hall, Westminster, London, S.W.1, at 7 p.m.

APRIL 13.

West Riding of Yorkshire Branch:—"Further Notes on Moulding Sands." Paper by S. Carter and A. W. Walker, at Technical College, Bradford.

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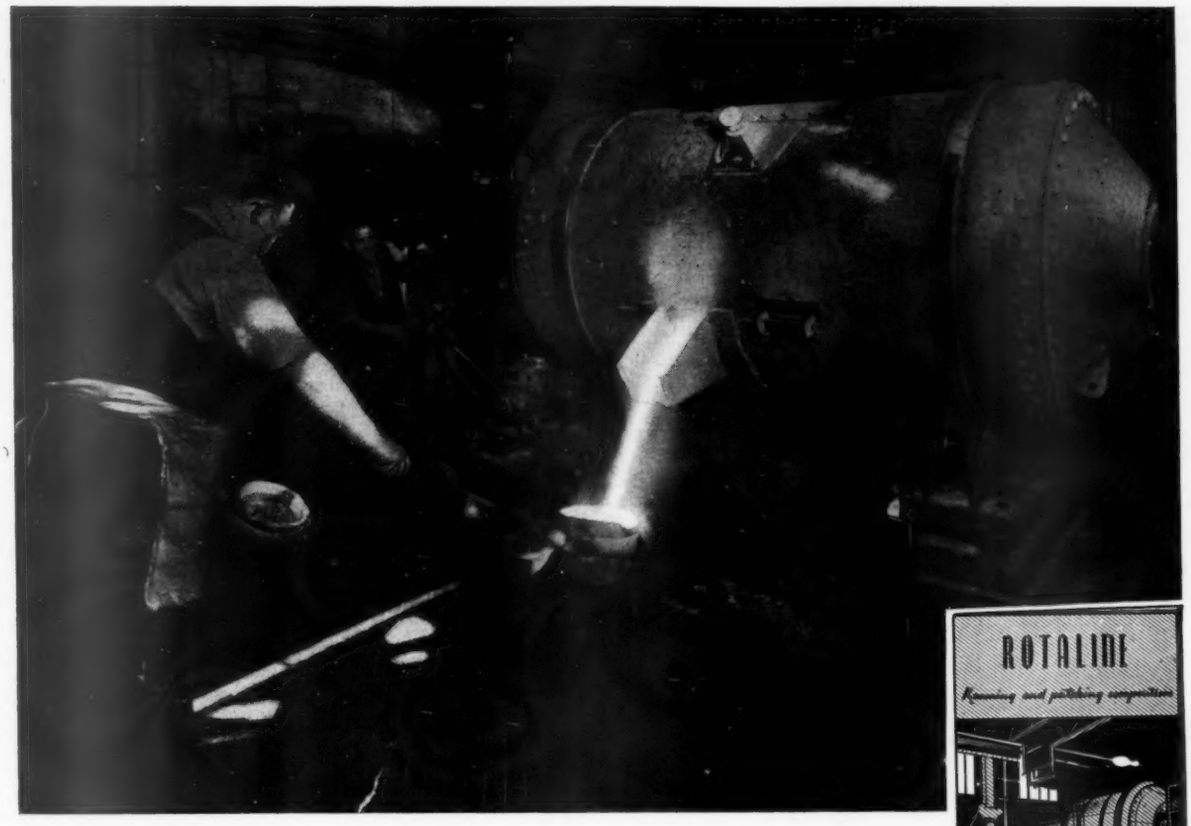
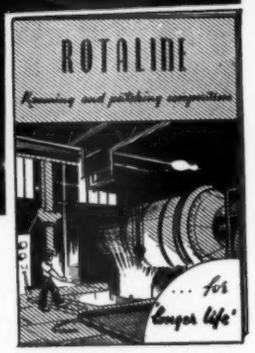


A Stein & Atkinson Rotar Furnace reproduced by the courtesy of Messrs. Peglers Limited, Doncaster.



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Raw Material Markets

All sections of the iron and steel industry have settled down again to normal outputs following the break in operations which many concerns were able to take at Easter. The position at the foundries changes but little from week to week; most of the heavy concerns are fully engaged on Government contracts, but there is a poor response to the efforts of light-castings makers to secure official work. It does not appear that these works will be able to play any important part in the nation's war effort for some time to come, although increasing use may be made of them as the war effort is intensified.

Pig-Iron

MIDDLESBROUGH—Foundries in this district continue to obtain their pig-iron requirements from other areas, owing to the suspension of the production of Cleveland iron. Fortunately, Midland ironmakers are able to despatch supplies at a satisfactory rate, and thus comparatively little inconvenience is caused to consumers, although, of course, the additional transport cost involved is a factor which cannot be lightly passed over. Activity in this centre is now confined to the manufacture of other descriptions of iron; iron for the steelworks is in very heavy demand, and full outputs are taken up.

The keen demand for East Coast hematite is still maintained. The Easter vacation permitted makers to despatch supplies to works, which, in many instances, were idle, thus facilitating a certain amount of stocking, but the majority of makers have little reserve iron on which to draw and are relying on current outputs. It is hoped to expand production by the lighting of an additional blast furnace.

LANCASHIRE—Certain furnaces previously engaged on the manufacture of foundry iron have recently been changed over to basic iron, thus reducing the available supply of the former. Deliveries are coming to hand quite well, however, though there is little surplus. Light-castings makers remain slack and their pig-iron requirements are easily met. Jobbing foundries, on the whole, are fairly busy, while the textile machinery branch is moderately well placed for orders. The greatest pressure is still from the speciality engineering section, and consumption is very heavy among these concerns, which are mostly satisfying the needs of Government departments. West Coast hematite is being taken up quite freely, with deliveries being sent forward satisfactorily.

MIDLANDS—Apart from the sluggish demand for high-phosphorus qualities, the iron trade in the Midlands is very active. There is particular pressure for low-phosphorus iron, while hematite is also well taken up. The light-castings industry, the main user of high-phosphorus iron, is working at a low ebb, owing largely to the loss of the export trade and the curtailment of building activities. There are unlikely to be any substantial outlets for the light-castings industry unless a part of Government contracts can be diverted to this section. On the other hand, heavy engineering concerns are unable to accept much work in view of the large amount handed out by various Government departments. Supplies of low-phosphorus iron and hematite, used mainly by these concerns, are not easily to be acquired, but efforts to improve the situation are expected to be made before inadequacy of supplies really develops.

SCOTLAND—Firm conditions continue to prevail in the Scottish pig-iron market, all grades being in strong demand. Outputs are moving away rapidly, giving both producers and consumers little opportunity to accumulate stocks. Intermittent working is still the rule in the light-castings trade, some works being better placed than others.

Coke

The desire to book ahead their requirements of foundry coke is still being expressed by users, and quite a fair amount of business has been done up to the end of June, which is as far forward as makers will commit themselves at this juncture. The minimum price of Durham best foundry coke, for delivery to Birmingham and Black Country stations, is 50s. 6d. per ton, this price being subject to change at any time.

Steel

High hopes are centred on the new scheme for the distribution of steel, as a result of which it is intended that deliveries shall go where they are most needed; in other words, consumers generally must be engaged on work of national importance and actually require to use the steel at an early date after delivery. This will doubtless reduce, if not eradicate, the number of buyers who in the past have been able to acquire supplies before they were needed or for ordinary civil work of a comparatively unimportant nature. Much of the uncertainty hitherto existing with regard to steel will now be removed, as it is intended that users will be informed well in advance of the tonnage they may expect to receive over a set period. Keen pressure exists in all departments of the industry, and producing works are operating at highly gratifying levels in order to comply with their commitments.

Scrap

An increased movement of deliveries has been noticeable in the scrap iron and steel market in all parts of the United Kingdom following the introduction of the higher prices recently. This is satisfactory, as the demand is insatiable, but supplies will have to be forthcoming more speedily if the importation of scrap is to be reduced, or, better still, suspended. It is, of course, in the interests of the nation to keep down imports, owing to the heavy costs, both in sterling and human lives, and scrap is one of the materials which should be imported as little as possible on account of its bulk. Steelworks are leading the pressure for supplies, but there is also a strong demand from other sources. The campaign to bring into use the vast amount of old metal at present lying idle on farms, etc., is not being neglected, and quite a good response is meeting the strenuous efforts which are being made in this respect.

Metals

The London tin market has remained on the dull side. The East has been selling between 400 and 600 tons a day recently, but as the International Tin Committee's 80 per cent. quota for the second quarter came into operation on Monday, it is unlikely that so much will in future be available. Continental demand for tin is substantial, but the difficulty is to procure export licences. Following the recent Anglo-Spanish Agreement, it is now somewhat easier to obtain licences for this country.

Comment on the condition of the American tin market is contained in a recent review by C. S. Trench & Company, Inc., metal dealers, of New York, who state that, "so far there have been no signs of any improvement in the consumption of tin in the principal consuming industries, and the operating rate of 55 per cent. which prevails in the tinplate trade is probably representative of the operations in other lines. However, starting with April, there should be the customary seasonal improvement, although it is a matter of guess-work to say what this will amount to. It now seems that the action of the Tin Committee in reducing the export quota to 80 per cent. for the second quarter may not pinch the market, as it was thought at the time it might do. During January and February exports from Malaya were only 11,935 tons, equivalent to 90 per cent. of standard tonnages, against a permitted rate of 120 per cent. Malaya has, therefore, accumulated arrears of 5,880 tons, and if it suits the producers in that territory, the exports during the second quarter can run over 100 per cent., notwithstanding the 80 per cent. quota."

Malayan tin ore exporters will pay an *ad valorem* duty of 2½ per cent. of the value of the ore, following the adoption by the Federal Council at Kuala Lumpur on Monday of the War Taxation Bill. Rubber exporters will pay an *ad valorem* additional duty of 2½ per cent. of the value of the commodity exported. The additional export duty for both commodities does not affect companies incorporated in England, as they are subject to British income tax on their profits. The tax is effective until the end of the year, when it is renewable. The proceeds of the taxation, estimated to produce 8,000,000 Straits dollars (£933,000) annually, will be offered to the Imperial Government, and will permit the F.M.S. to give not less than £1,000,000 a year as a contribution to the war effort. The Straits Settlements Legislative Council met at Singapore on Tuesday, when a Bill, similar to that in the Federated States, was introduced.

Metal Exchange prices for tin this week have been as follow:—

Cash—Thursday, £247 15s. to £248; Friday, £248 5s. to £248 10s.; Monday, £245 15s. to £246 5s.; Tuesday, £248 15s. to £249; Wednesday, £249 10s. to £249 15s.

Three Months—Thursday, £246 to £246 5s.; Friday, £246 to £246 5s.; Monday, £243 10s. to £243 15s.; Tuesday, £246 10s. to £247; Wednesday, £247 to £247 10s.

Owing to the Control which exists over the copper trade in the United Kingdom, there is little to report from week to week. Consumption is undoubtedly maintained at a high rate, but market developments are now precluded by the emergency measures introduced to ensure that available supplies are delivered into the right channels. A very quiet tone still prevails in the United States copper market, and business has been very slow to materialise. Sales in February were high, but the returns for March are likely to make a very poor showing; in the first half of the month little more than 10,000 short tons had been involved in transactions.

There has been considerable interest of recent months in the position created by the large-scale deliveries of American copper to the Soviet Union. The effect of the proposed Allied endeavours to strengthen the blockade of Germany will be followed closely; already the Royal Navy has detained at Hong Kong a Soviet vessel laden with copper and molybdenum from the U.S.A. and destined for Vladivostock. There was much resentment in the States that Russia was obtaining supplies of metal from American sources during the period of Soviet onslaught on Finland, but the possibility of these deliveries finding their way "through the back door" to augment Germany's resources will undoubtedly occupy increasingly the attention of the British Government in the future. In fact, in reply to a question in the House recently, the Minister of Economic Warfare said there was evidence of large Soviet purchases from the United States of certain war materials, especially copper, and this matter was receiving the constant attention of H.M. Government. Through the Soviet buying agency in America, the Amtorg Trading Corporation, Russia has been offering to buy supplies at prices in excess of the current quotations. It is reported that only one large American producer has been willing to sell to the U.S.S.R. At the same time, the Soviet has been able to acquire metal through brokers on the New York Commodity Exchange.

Spelter and lead continue to be taken up in large tonnages by firms engaged on war contracts; for other purposes licences are granted only sparingly.

Patent Specifications Accepted

The following list of Patent Specifications accepted has been taken from the "Official Journal (Patents)." Printed copies of the full Specifications are obtainable from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each. The numbers given are those under which the Specifications will be printed and abridged, and all subsequent proceedings will be taken.

517,442 GENERAL ELECTRIC COMPANY, LIMITED, and SMITHELLS, C. J. Alloys and their manufacture.

517,443. OESTERREICHISCHE MAGNESIT AKT.-GES. Construction of mortarless refractory brickwork.

517,466 KLINGE, W. H. E. Metal-feeding device for melting-pots.

517,567 EVANS, O. (Rekuperator Ges.). Steel-smelting furnaces.

517,570 LERMER, A. Refractory blocks for the checker work of furnaces for industrial purposes.

517,600 HOWDEN & COMPANY, LIMITED, J., and FLEMING, J. T. Rotary heat-exchangers suitable for heating air by furnace gases.

517,916 BOYLE, C. L. Method of treating iron or steel surfaces.